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PROGRESS REPORT

ANALYSIS OF SCANNER DATA FOR CROP INVENTORIES

Period Covered:
7 June 1979 Through 14 September 1979

Program Manager: Quentin A. Holmes
Technical Manager: Robert Horvath
Task Coordinators: Richard C. Cicone
Richard J. Kauth
William A. Malila

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Prepared For:
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Johnson Space Center
Houston, Texas 77058
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15. Supplementary Notes

16. Abstract

This report summarizes the progress on subject contract during the second quarter. A generalized description of approaches and interim results are provided for this program of developing objective labeling techniques and the machine processing techniques within which the former will be embedded.

17. Key Words	18. Distribution Statement
Crop Inventory, Landsat, LACIE, Wheat Inventory, Sampling, Crop Modeling, Temporal Profile Fitting, Analyst Labeling	

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PREFACE

The following report serves as the Quarterly Report for Contract NAS9-15476 which is entitled "Analysis of Scanner Data for Crop Inventories". This report describes the work carried out under that contract for the period 7 June 1979 through 14 September 1979.

Work on this contract is performed in the Infrared and Optics Division directed by Mr. Richard R. Legault. Dr. Quentin A. Holmes is the Program Manager for this contract and Mr. Robert Horvath is the Technical Manager.

This contract is part of a comprehensive and continuing program of research concerned with advancing the state-of-the-art in remote sensing of the environment from aircraft and satellites. The research is being carried out for NASA's Lyndon B. Johnson Space Center (JSC), Houston, Texas, by the Environmental Research Institute of Michigan (ERIM). The basic objective of this multidisciplinary program is to develop such information systems as practical tools which will provide planners and decision-makers extensive accurate information quickly and economically.

Progress during the reporting period was made in a number of areas, including: 1) Development of a standardized procedure for handling the mathematics of crop spectral/temporal profile characterization; 2) Development and initiation of an approach to deriving crop growth stage estimators from Landsat MSS data; 3) Development of a long-range perspective on crop inventory system design; and 4) Preliminary analysis of the analyst labeling/Procedure M experiment. These efforts were reported orally at the Supporting Research and Technology (S.R.&T.) Quarterly Review held at NASA/JSC on 10-14 September 1979. The materials which constitute this Quarterly Report are the visual aids from that presentation.

THIRD QUARTERLY PROGRESS REVIEW

ON

ANALYSIS OF MULTISPECTRAL SCANNER DATA FOR CROP INVENTORIES

CONTRACT NAS9-15476

ENVIRONMENTAL RESEARCH INSTITUTE OF MICHIGAN

PRESENTED AT

JOHNSON SPACE CENTER, HOUSTON, TEXAS

SEPTEMBER 1979

CONTENTS/AGENDA

SYNOPSIS OF TASKS

OBJECTIVE LABELING

- FEATURE DEFINITION
  - SPECTRAL/TEMPORAL/SPATIAL
  - LANDSAT DATA STRUCTURE
- SIGNATURE CHARACTERIZATION
  - CROP SPECIFIC/TEMPORAL TRAJECTORY STATISTICS/GENERALIZED SIGNATURES
- LABELING TECHNIQUES DEVELOPMENT
  - AI AIDS/MACHINE LABELING/UNDERSTANDING LABELING ERRORS

MACHINE PROCESSING

- DATA NORMALIZATION
  - LANDSAT CALIBRATION/ATMOSPHERE EFFECT CORRECTION
- STRATIFICATION, SAMPLING AND ESTIMATION
  - FIELD DEFINITION/BIAS AND VARIANCE REDUCTION
- ERROR MODEL DEVELOPMENT
  - SYSTEM ANALYSIS/PERFORMANCE MEASURES
- TEST AND EVALUATION
  - SYSTEM VERIFICATION/GENERATE NEW HYPOTHESES
- ADVANCED TECHNOLOGY
  - CRITICAL ANALYSIS OF FUTURE NEEDS

PROFILE FITTING FOR GENERALIZED CROP DEVELOPMENT CHARACTERIZATION

SEPTEMBER 1979

PRESENTED BY:

ERIC P. CRIST

TERMINOLOGY

PROFILE: A MATHEMATICAL REPRESENTATION OF THE TEMPORAL DEVELOPMENT OF A GIVEN CROP IN A GIVEN SPECTRAL SPACE.

FOR THIS STUDY

SPECTRAL SPACE: TASSELED-CAP GREENNESS.

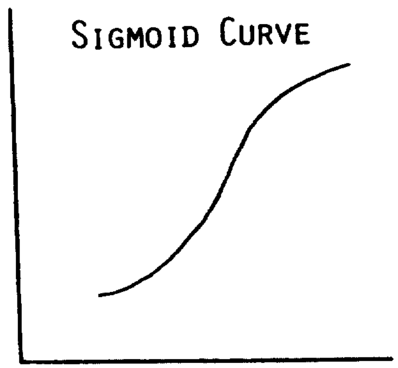
CROP: SPRING WHEAT (WITH APPLICATION TO MOST OTHER CROPS WITH A SINGLE GREEN-UP PHASE).

OUTLINE OF PRESENTATION

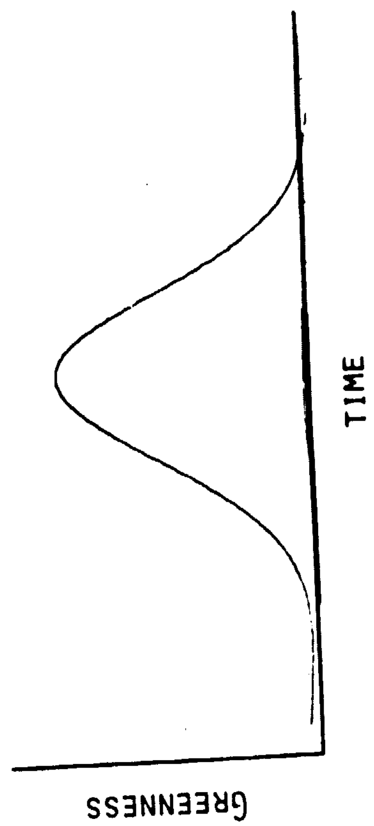
- BACKGROUND - PROFILES AND THEIR APPLICATIONS
- USE OF PROFILES AS SOURCES OF NEW FEATURES
- NEW MODEL FORM - DESCRIPTION AND EVALUATION
- RECOMMENDED PROCEDURE FOR PROFILE-FITTING

UNDERLYING ASSUMPTIONS

- Crop development on a field level is a continuous process (gradual versus abrupt changes).
- The accompanying spectral changes are likewise continuous.
- Both processes can be characterized by a Sigmoid-shaped curve (typical of most biological phenomena).



SIMPLE MODEL



USES OF PROFILES

- THERE ARE A WIDE VARIETY OF POSSIBLE APPLICATIONS
- DIFFERENT APPLICATIONS PUT DIFFERENT DEMANDS ON THE MODEL FORM
- MODELS WHICH ARE ADEQUATE AT ONE LEVEL MAY NOT BE ADEQUATE AT OTHER LEVELS

LEVEL 1 - GENERALIZED FORM

<u>REQUIREMENT</u>: ROUGH APPROXIMATION OF TEMPORAL DEVELOPMENT

SIMPLEST CASE - LINEAR INTERPOLATION BETWEEN OBSERVATIONS

<u>EXAMPLE USES</u>: ESTIMATION OF CROP CALENDAR SHIFT, STRATIFICATION

LEVEL 2 - ESTIMATION OF A PARTICULAR SPECTRAL FEATURE

REQUIREMENT: ACCURATE REPRESENTATION OF THAT PART OF THE PROFILE RELATED TO FEATURE OF INTEREST

NEEDN'T CHARACTERIZE OVERALL DEVELOPMENT ACCURATELY

EXAMPLE USES: ESTIMATION OF MAXIMUM GREENNESS

LEVEL 3 - CHARACTERIZATION OF MULTIPLE CROP FEATURES, OVERALL SPECTRAL DEVELOPMENT

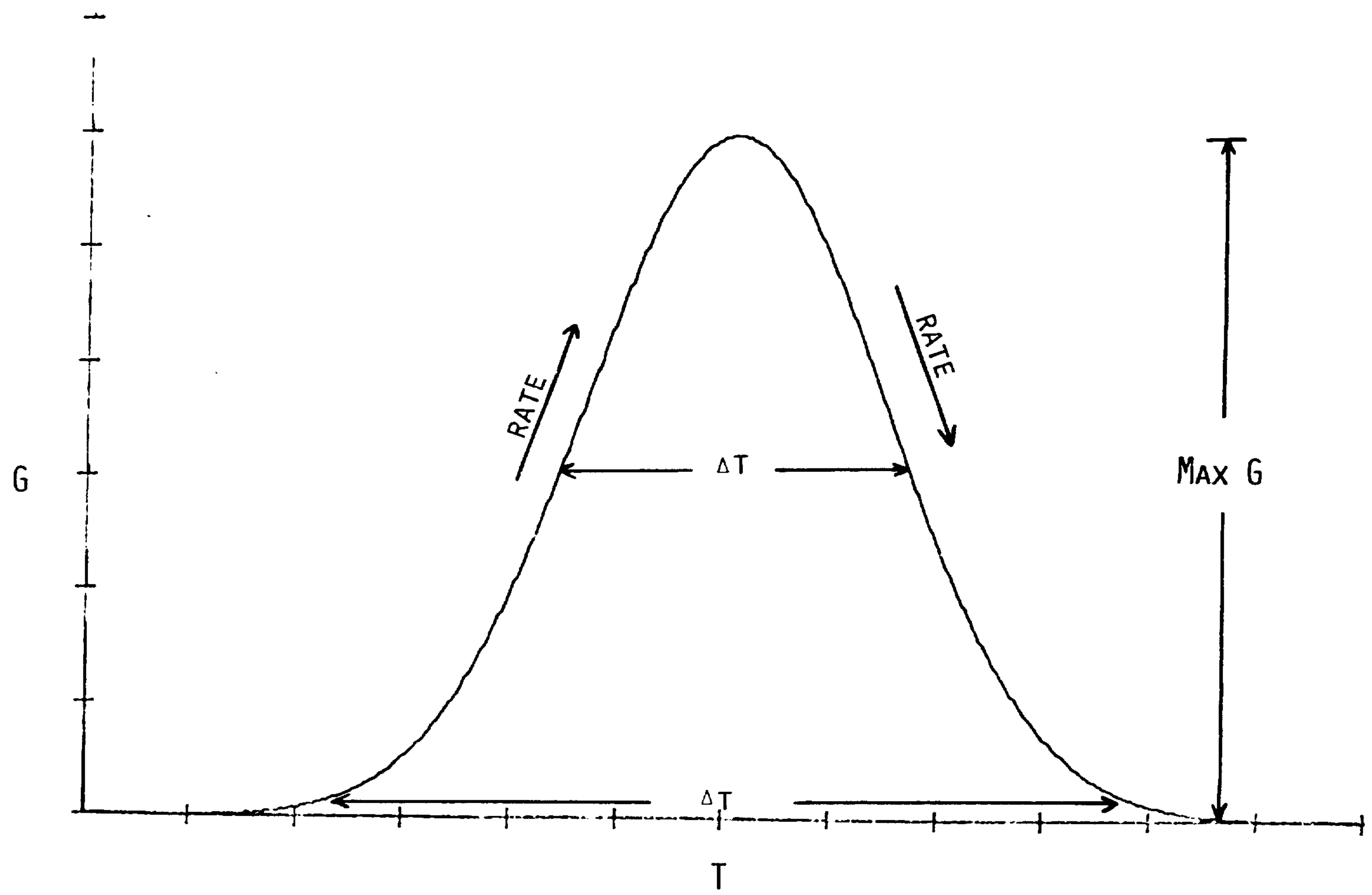
REQUIREMENT: ACCURATE FIT TO DATA THROUGHOUT GROWING SEASON

EXAMPLE USES: EXTRACTION OF NEW FEATURES FOR CROP CONDITION ASSESSMENT, LABELING, ETC.

POTENTIALLY USEFUL FEATURES:

- PEAK GREENNESS
- RATE OF GREEN-UP
- RATE OF GREENNESS DECLINE
- TEMPORAL CHANGE IN RATE OF GREENNESS DEVELOPMENT
- TOTAL DEVELOPMENT TIME
- PERIOD OF TIME BETWEEN HALF-AMPLITUDE POINTS

USEFUL PROFILE FEATURES



LEVEL 4 - SUBSTITUTION FOR MISSING DATA

<u>REQUIREMENT</u>: VERY ACCURATE FIT, MECHANISM FOR SENSIBLE INTERPOLATION BASED ON HISTORIC INFORMATION, AGRONOMIC UNDERSTANDING

<u>EXAMPLE USE</u>: CHARACTERIZATION OF GENERAL WHEAT SIGNATURE

ORIGINAL MODEL FORM

<u>APPLIED TO SMALL GRAINS</u>

$$F(T) = AT^B \, EXP(CT^2)$$

F(T) = GREENNESS - 25

T = SHIFTED DAY OF YEAR - 125

A, B, C = MODEL PARAMETERS

ASSUMES CROP CALENDAR SHIFT ESTIMATION CARRIED OUT

- MOVES ALL DATA TO STANDARD TIME FRAME

CHARACTERISTICS OF ORIGINAL MODEL

$$F(T) = AT^{B}\ EXP(CT^{2})$$

- ACCOMMODATES ASSUMPTIONS
  - NO SHARP CORNERS
  - DOUBLE SIGMOID SHAPE (MORE PRONOUNCED ON DOWNWARD SIDE)
- LOCAL PHENOMENA HAVE GLOBAL EFFECTS - ONE FUNCTION IS MADE TO FIT ALL DATA (LEAST SQUARES)
  - PROVIDES MEANS OF FILLING IN MISSING DATA
  - MAY RESULT IN POORER FIT IN SOME CASES
- CAN BE LINEARIZED FOR EASY PARAMETER ESTIMATION
  - $\mathrm{LN}\ F(T) = \mathrm{LN}\ A + BT + CT^{2}$

MODEL APPLICATIONS TO DATE

- ESTIMATION OF CROP CALENDAR SHIFT (LEVEL 1)
- ESTIMATION OF PEAK GREENNESS FOR MOISTURE STRESS DETECTION (LEVEL 2)
- UCB'S EPISODAL EVENTS TASK (LEVEL 2)

STUDY OF LEVEL 3 MODEL APPLICATION
OVERALL CROP SPECTRAL DEVELOPMENT CHARACTERIZATION

GOALS

- TO DEMONSTRATE THE NEED FOR OFFSETTING
- TO COMPARE PARAMETER ESTIMATION METHODS
- TO EVALUATE USE OF FIELD MEANS
- TO BEGIN TO FORMULATE A PROCEDURE FOR FITTING MODEL TO FIELDS OR OTHER SAMPLING UNITS

STUDY OF LEVEL 3 MODEL APPLICATION

- DATA FROM SELECTED FIELDS IN THREE PHASE 3 BLIND SITES
  - SUBSET OF FIELDS FOR WHICH PERIODIC OBSERVATIONS WERE RECORDED
  - ONE-PIXEL INSETS AT FIELD BOUNDARIES
- PROCESSING
  - SENSOR CALIBRATION
  - SUN ANGLE CORRECTION
  - SCREEN OUT BAD DATA, CLOUDS, ETC.
  - SPATIALLY-VARYING XSTAR HAZE CORRECTION
  - CROP CALENDAR SHIFT ESTIMATION

IMPORTANCE OF OFFSETTING

MODEL CONSIDERATIONS

$$F(T) = AT^{B} \, EXP(CT^{2})$$

- MODEL IMPLICITLY CONSIDERS THE RANGE

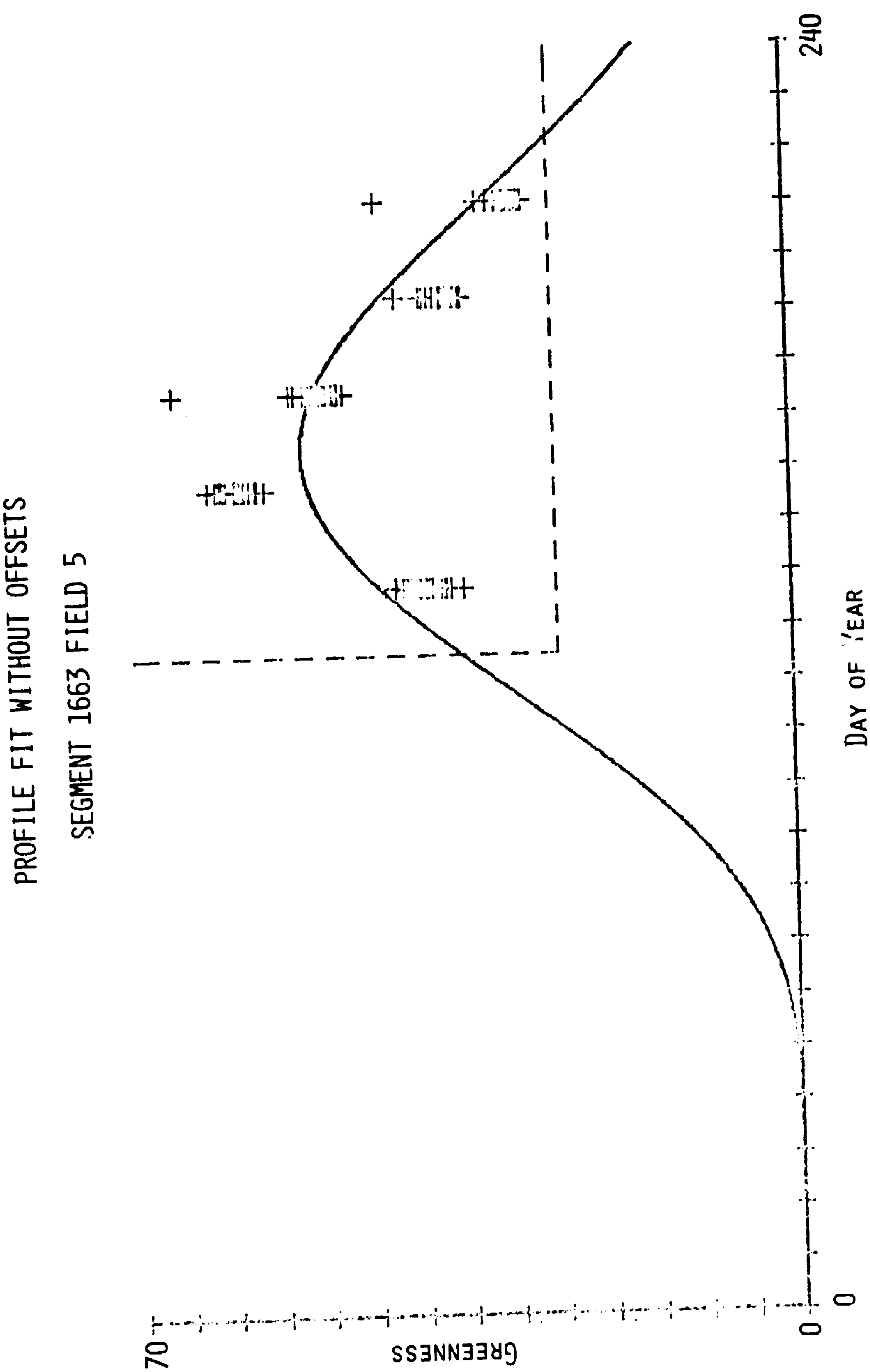
  $T = 0$ THROUGH $T = \infty$

  AND

  $F(T) = 0$ THROUGH $F(T) = MAX$

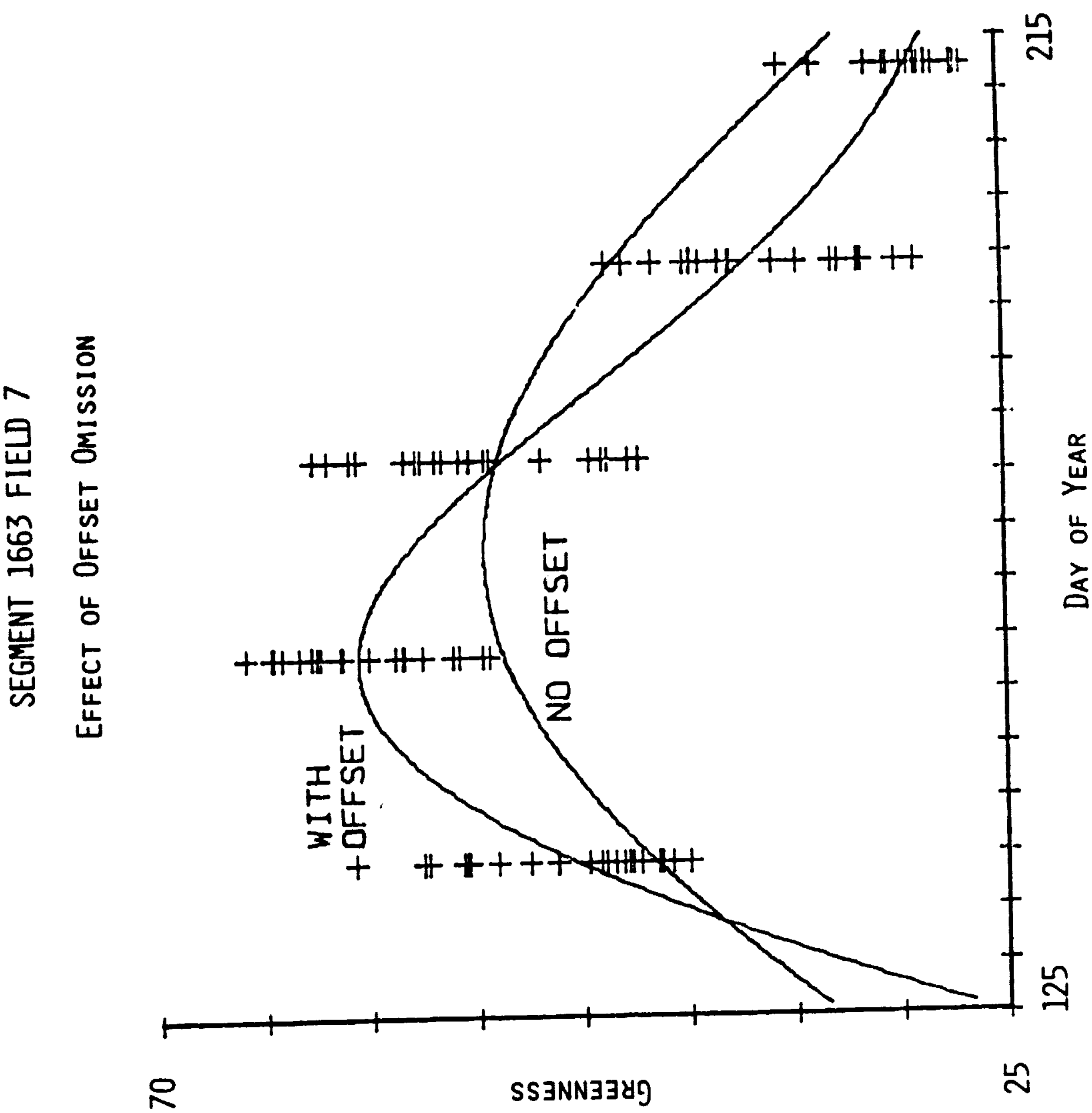
- DESIRED SIGMOID SHAPE SIMILARLY STARTS AT

  $T = 0, F(T) = 0$


PROFILE FIT WITHOUT OFFSETS
SEGMENT 1663 FIELD 5
GREENNESS
70
0
0
240
DAY OF YEAR

IMPORTANCE OF OFFSETTING (CONT.)
TEST RESULTS

- LINEAR REGRESSION USED TO ESTIMATE PARAMETERS WITH AND WITHOUT OFFSET
- RESULTS SHOWED MARKED DECLINE IN GOODNESS-OF-FIT WHEN OFFSETTING WAS OMITTED
  - LOW PEAK ESTIMATE
  - LOSS OF SIGMOIDAL SHAPE IN RANGE OF DATA
  - MIS-REPRESENTATION OF OTHER FEATURES


SEGMENT 1663 FIELD 7
EFFECT OF OFFSET OMISSION
WITH OFFSET
NO OFFSET
70
GREENNESS
25
125
215
DAY OF YEAR

METHODS OF PARAMETERS ESTIMATION

ORIGINAL APPROACH: MULTIPLE LINEAR REGRESSION (MLR)

$$\ln F(T) = \ln A + B + CT^2$$

MLR MINIMIZES: $\sum(\ln F(T) - \ln G_I(T))^2$

PROBLEMS:

- NON-LINEAR NATURE OF LOG TRANSFORM COMPRESSES PEAK, RESULT IS LOWER THAN DESIRED ESTIMATE OF PEAK
- GIVES GREATER WEIGHT TO LOW VALUES (TAILS OF PROFILES)

$$\sum(\ln F(T) - \ln G_I(T))^2 = \sum\left(\ln\left(\frac{F(T)}{G_I(T)}\right)\right)^2$$

METHODS OF PARAMETER ESTIMATION (CONT.)

ALTERNATIVE - NON-LINEAR LEAST SQUARES ESTIMATION

- USED MODIFIED LEVENBERG-MARQUARDT STEEPEST DESCENT ALGORITHM*
  - ITERATIVE APPROACH: COMPARES SUCCESSIVE PARAMETERS ESTIMATES
- AVOIDS NEED FOR LOG TRANSFORMATION
- MINIMIZES $\sum (F(T) - G_I(T))^2$
  - EQUAL WEIGHTING THROUGHOUT PROFILE

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*FROM INTERNATIONAL MATHEMATICAL AND STATISTICAL LIBRARY

METHODS OF PARAMETER ESTIMATION (CONT.)

GOODNESS-OF-FIT MEASURE

- R^2 FROM REGRESSION IS MEASURE OF FIT IN LOG SPACE, NOT IN ACTUAL DATA SPACE
- NEED COMMON MEASURE FOR COMPARING ALTERNATIVE METHODS
- GOODNESS-OF-FIT DEFINED TO BE

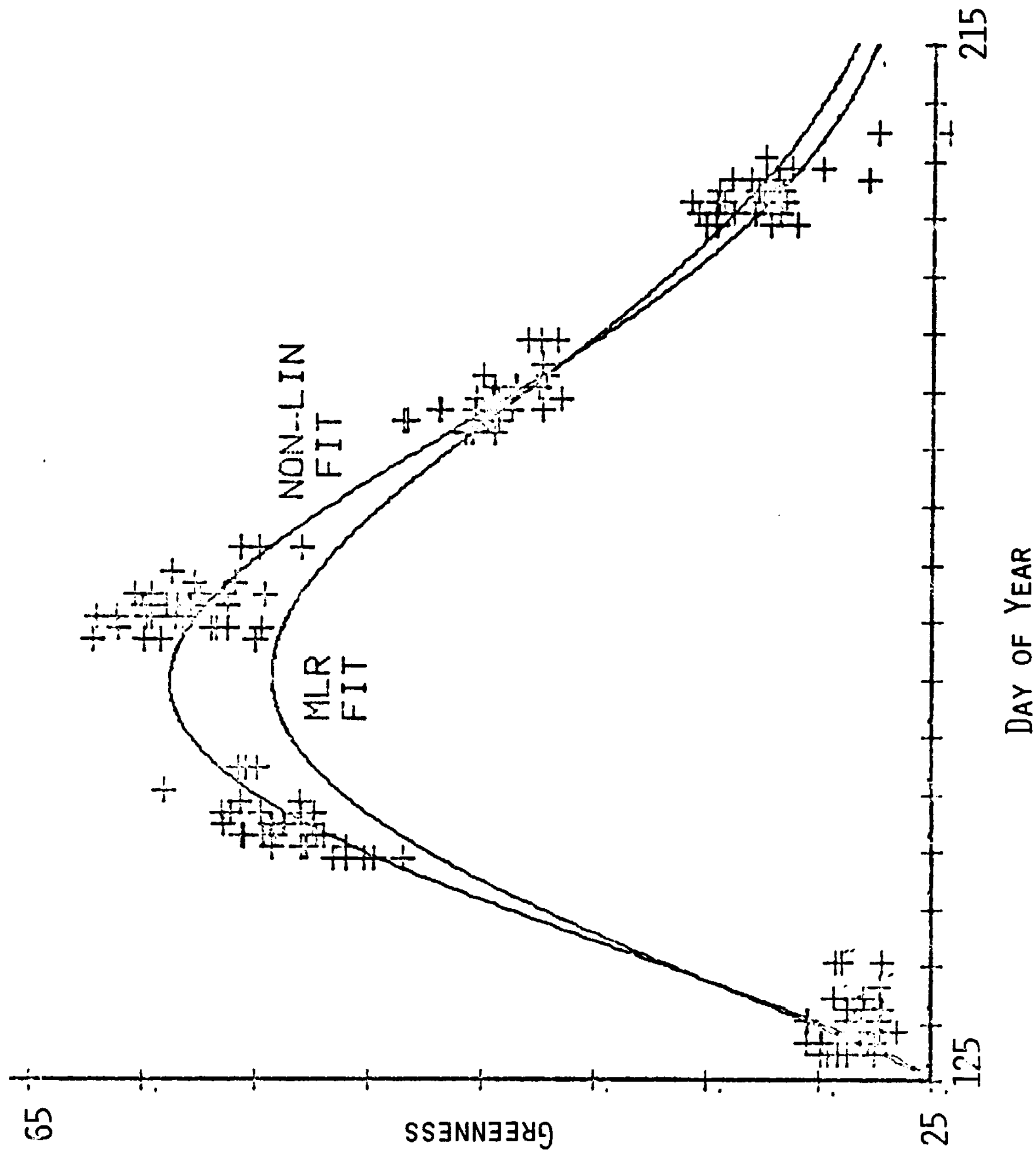
$$GFIT = 1 - \frac{\Sigma(F(T) - G_I(T))^2}{\Sigma(G_I(T) - \bar{G})^2}$$

METHODS OF PARAMETER ESTIMATION (CONT.)

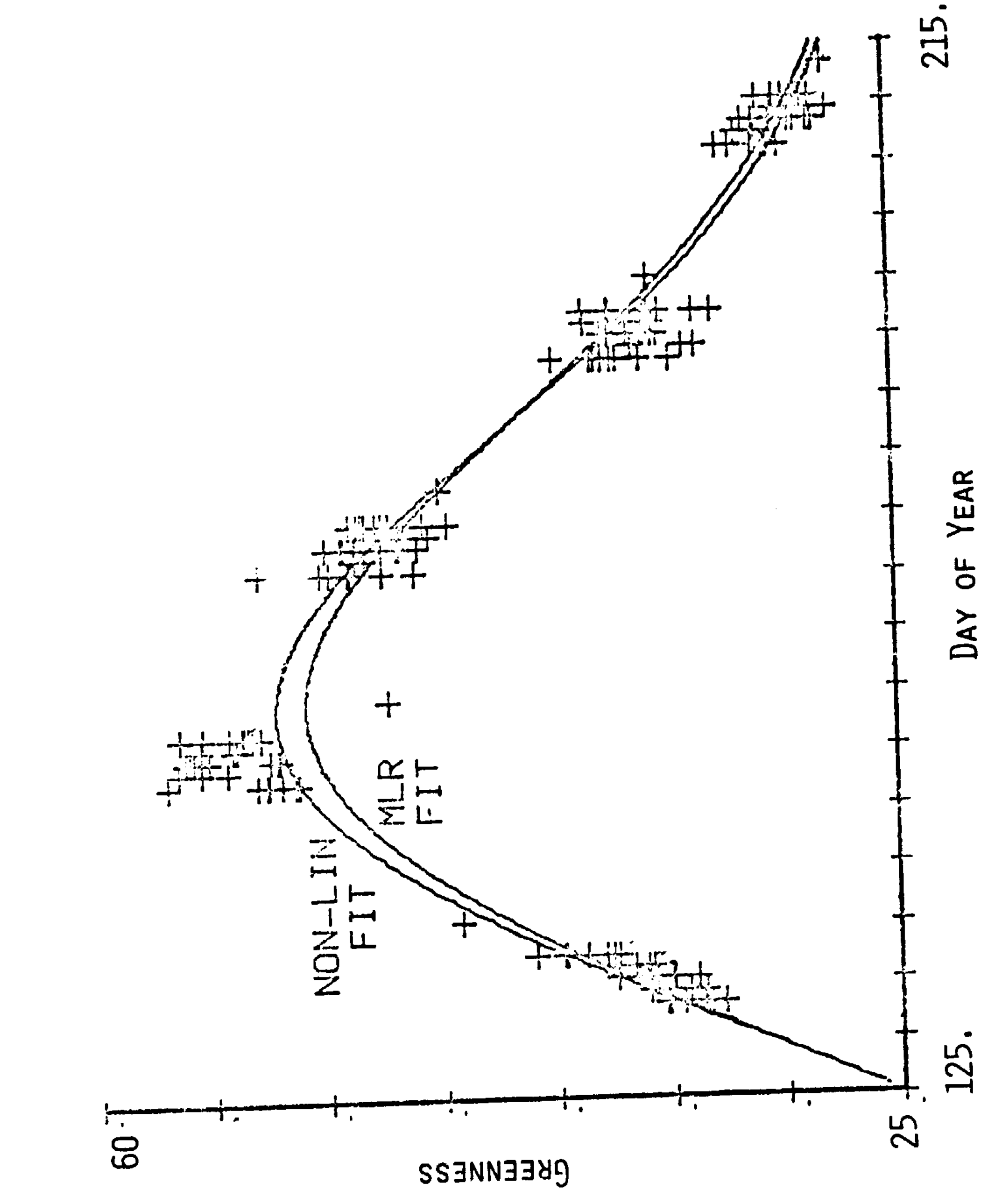
RESULTS OF COMPARISON

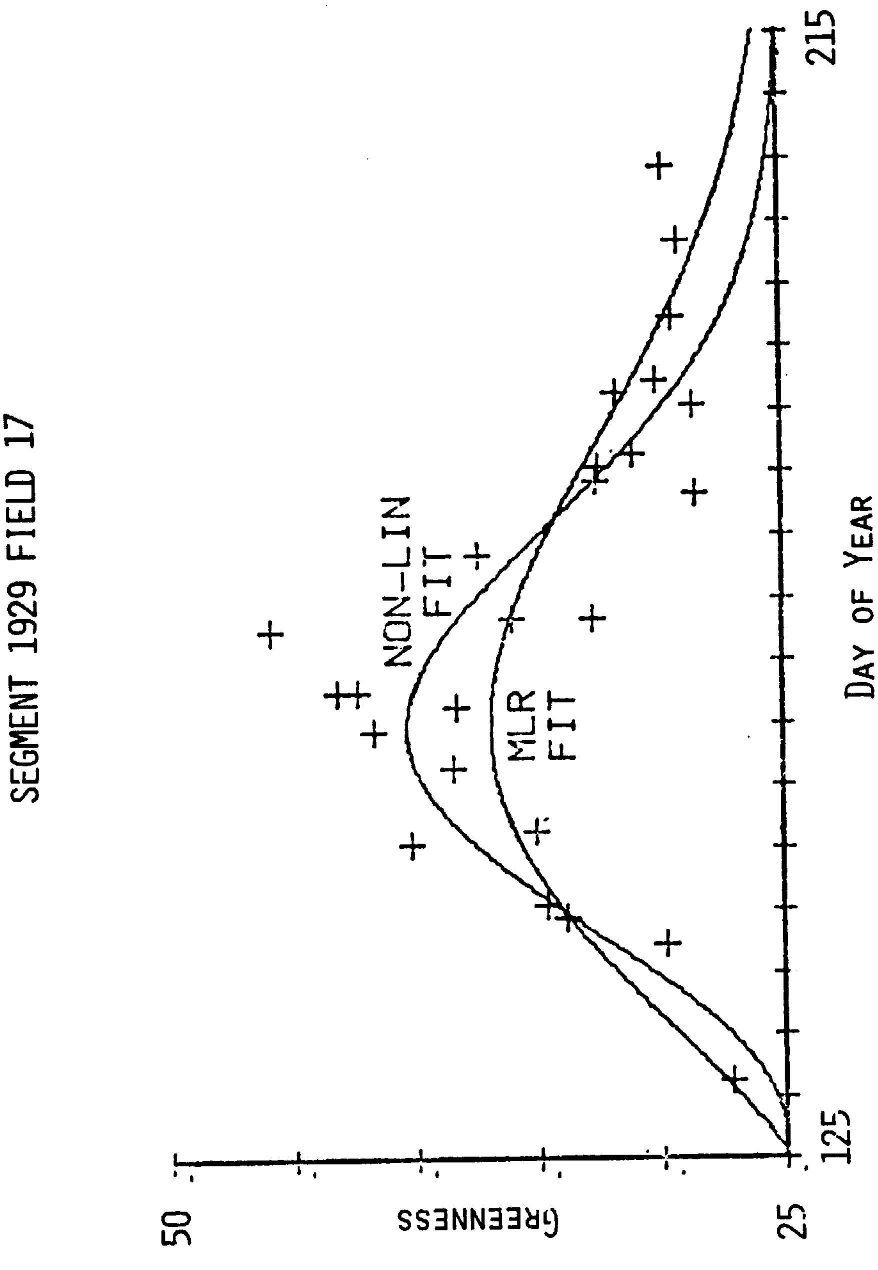
- NON-LINEAR METHOD PRODUCED BETTER PROFILE
  - BETTER GOODNESS-OF-FIT
  - BETTER PEAK ESTIMATE
- NON-LINEAR ESTIMATES MORE EXPENSIVE

SEGMENT 1663 FIELD 11



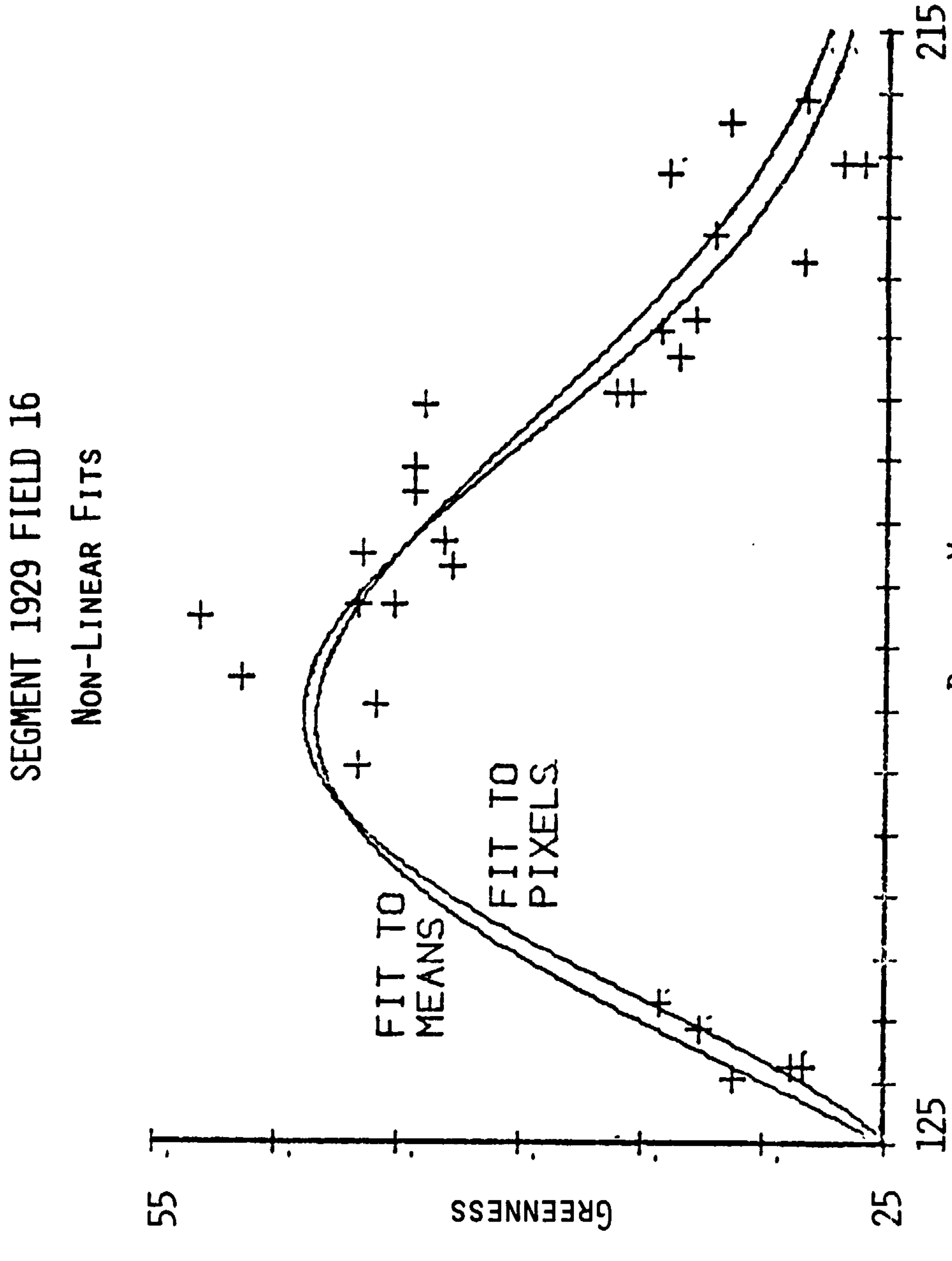
SEGMENT 1663 FIELD 14

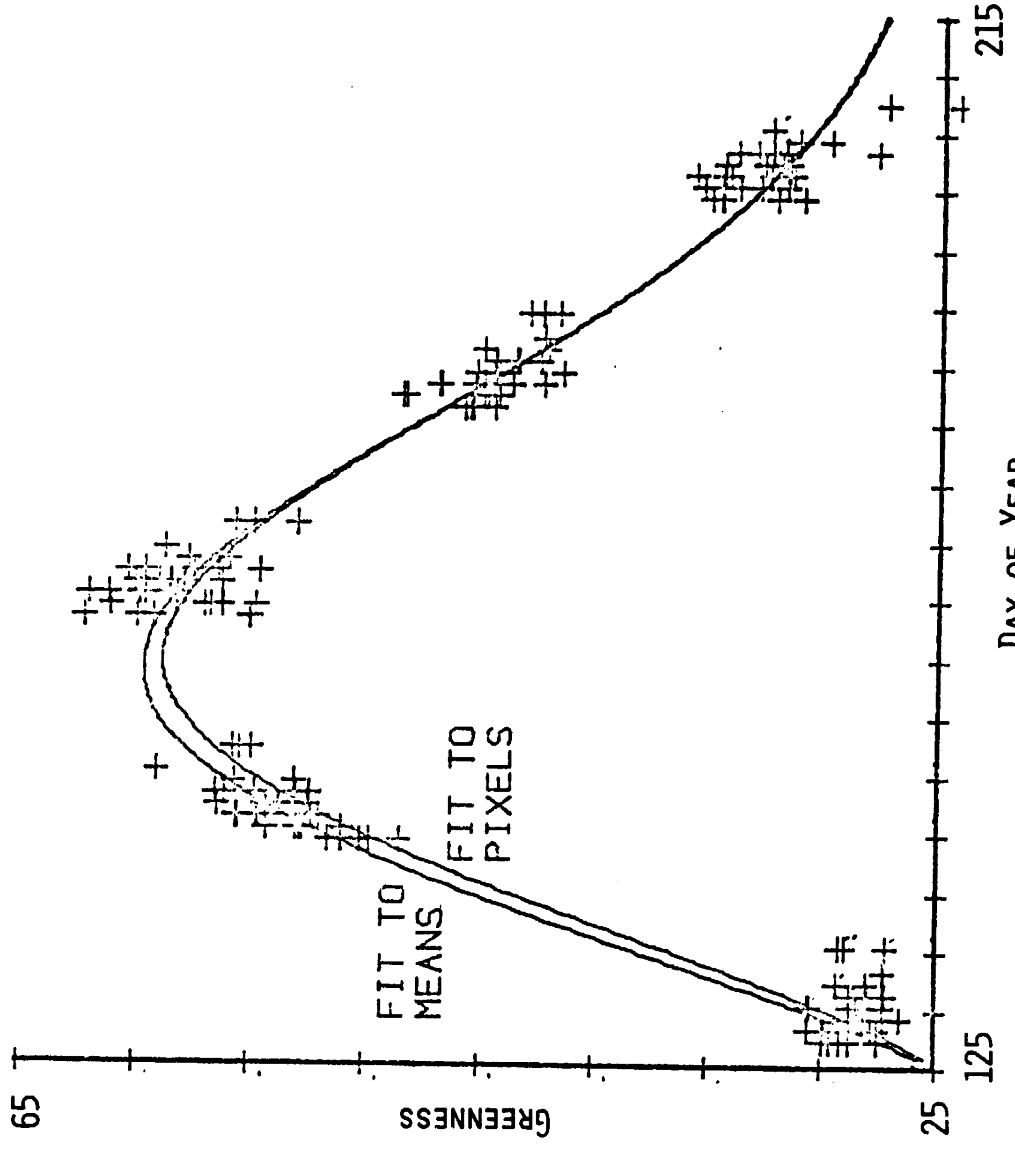



SEGMENT 1929 FIELD 17
NON-LIN FIT
MLR FIT
50
GREENNESS
25
125
215
DAY OF YEAR

USE OF FIELD MEANS

- ADVANTAGE - DATA COMPRESSION
- COMPARISON OF PIXELS VS MEANS (USING NON-LINEAR ESTIMATION TECHNIQUE)
  - IN MOST CASES, NO APPARENT SIGNIFICANT DIFFERENCE IN PROFILE PARAMETERS
  - WITH SEVERAL MISSING ACQUISITIONS, DEGREES OF FREEDOM REDUCED TO NEAR MINIMUM FOR STATISTICALLY VALID PARAMETER ESTIMATES


SEGMENT 1929 FIELD 16
NON-LINEAR FITS
FIT TO MEANS
FIT TO PIXELS
GREENNESS
55
25
125
215
DAY OF YEAR



SEGMENT 1663 FIELD 11
Non-Linear Fits

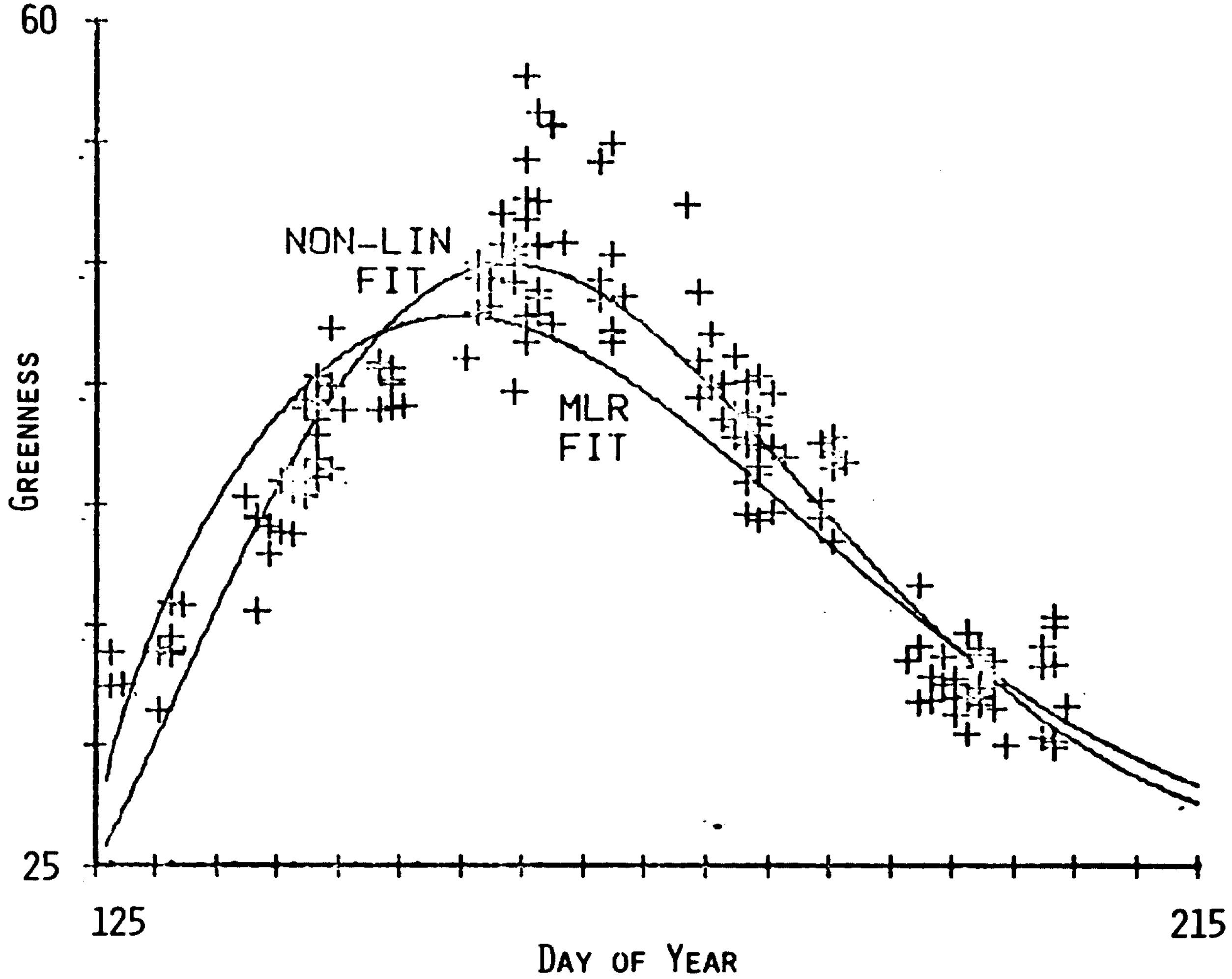
DATA OFFSETTING

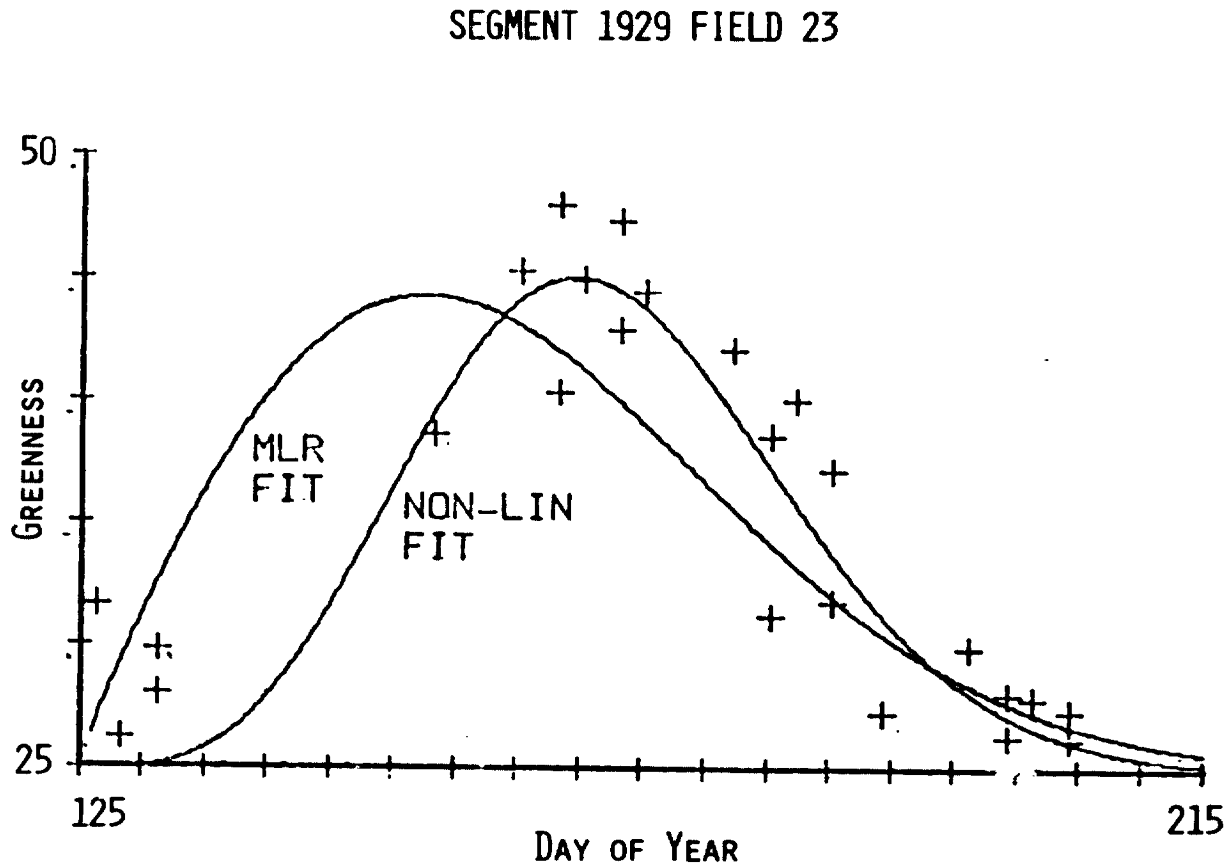
- MODEL IS INTENDED TO CHARACTERIZE SPECTRAL CHANGES FROM DETECTABLE EMERGENCE TO HARVEST OR NEAR-HARVEST
- THIS CONSTRAINT REQUIRES THAT DATA AXES BE OFFSET SUCH THAT SPECTRAL DEVELOPMENT STARTS AT OR VERY NEAR (0,0)
- BASED ON AVAILABLE DATA, OFFSETS WERE PREVIOUSLY DEFINED AS:
  - GREENNESS - 25 COUNTS
  - DAY OF YEAR - 125 DAYS (AFTER SHIFT)
- THESE STANDARD OFFSETS ARE NOT APPROPRIATE FOR ALL CASES

EFFECTS OF ERRORS IN OFFSETTING

- LINEAR REGRESSION ESTIMATES
  - DISTORTION OF PROFILE SHAPE DUE TO WEIGHTING AT TAILS
  - PEAK ESTIMATE LESS RELIABLE
- NON-LINEAR ESTIMATES
  - FIT IN EARLY SEASON IS POORER
  - PEAK AND LATER LESS AFFECTED
- FIELD MEANS (NON-LINEAR FIT)
  - ESTIMATE CONSIDERABLY DIFFERENT FROM THAT BASED ON PIXELS

SEGMENT 1669 FIELD 30





SEGMENT 1929 FIELD 23
50
25
GREENNESS
125
215
DAY OF YEAR
MLR
FIT
NON-LIN
FIT

DATA OFFSETTING

APPROACHES TO FIELD-SPECIFIC OFFSET DETERMINATION

- LINEAR INTERPOLATION USING OBSERVATIONS BEFORE PEAK

  DAY AT WHICH LINE INTERSECTS SOME CONSTANT GREENNESS VALUE IS ASSUMED TO BE DAY OF START-UP

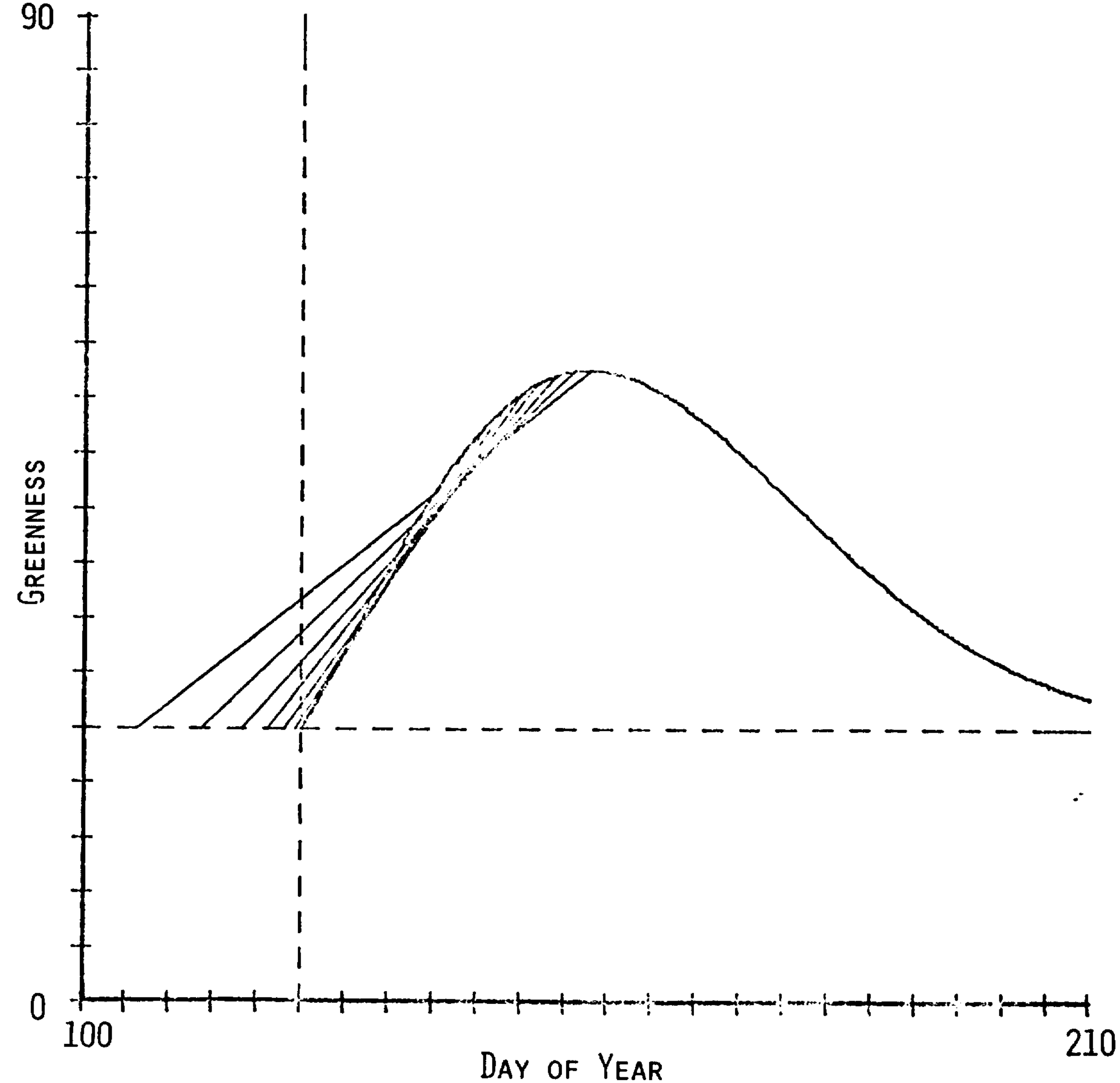
  - GREEN DEVELOPMENT IS NON-LINEAR; DAY OF INTERSECTION DEPENDS IN PART ON WHERE ALONG THE PROFILE OBSERVATIONS FALL
  - REQUIRES FIXED STARTING VALUE FOR GREENNESS

- INCLUSION OF OFFSETS AS MODEL PARAMETERS
  - INTERACTION OF TERMS -- PROGRAM UNABLE TO FIND SOLUTION

- ITEPATIVE PARAMETER ESTIMATION WITH VARYING OFFSETS
  - NO CLEAR BEST FIT ACHIEVED

SEGMENT 1663 FIELD 5

DAY OFFSET ESTIMATE USING STRAIGHT LINE



DATA OFFSETTING (CONT.)

- NO ACCEPTABLE METHOD FOUND FOR FIELD-SPECIFIC OFFSET DETERMINATION
- ALTERNATIVE SOLUTION -- NEW MODEL WHICH IS LESS DEPENDENT ON OFFSET

DATA OFFSETTING (CONT.)

FORMULATION OF NEW MODEL

$$F(T) = \begin{cases} A\ \mathrm{EXP}(B_1(T - T_P))^2; & T < T_P \\ A\ \mathrm{EXP}(B_2(T - T_P))^2; & T \geq T_P \end{cases}$$

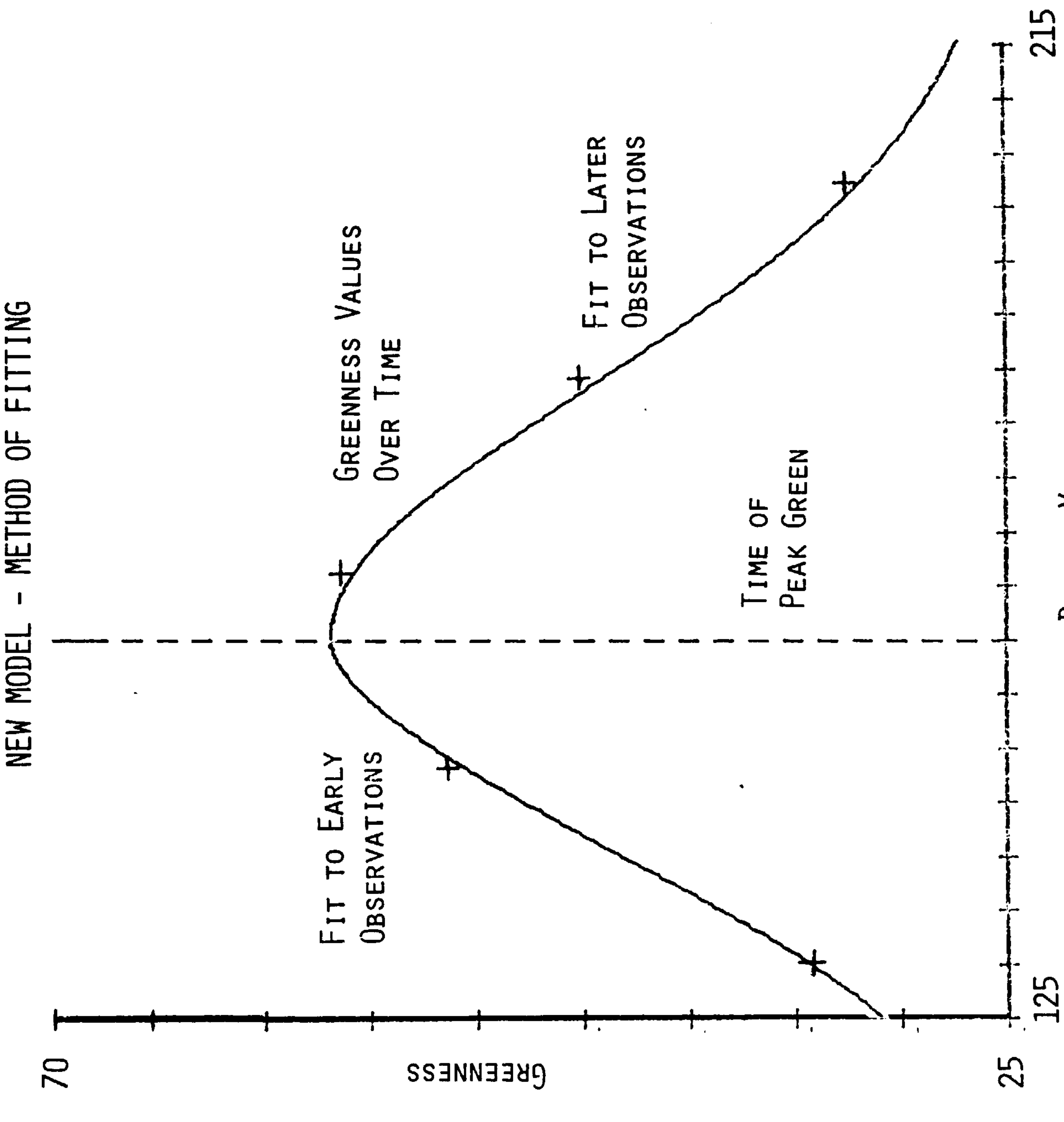
T = SHIFTED DAY OF YEAR

T_P = TIME OF PEAK GREENNESS

A, B_1, B_2 = PARAMETERS (WHERE A = ESTIMATED PEAK GREENNESS)

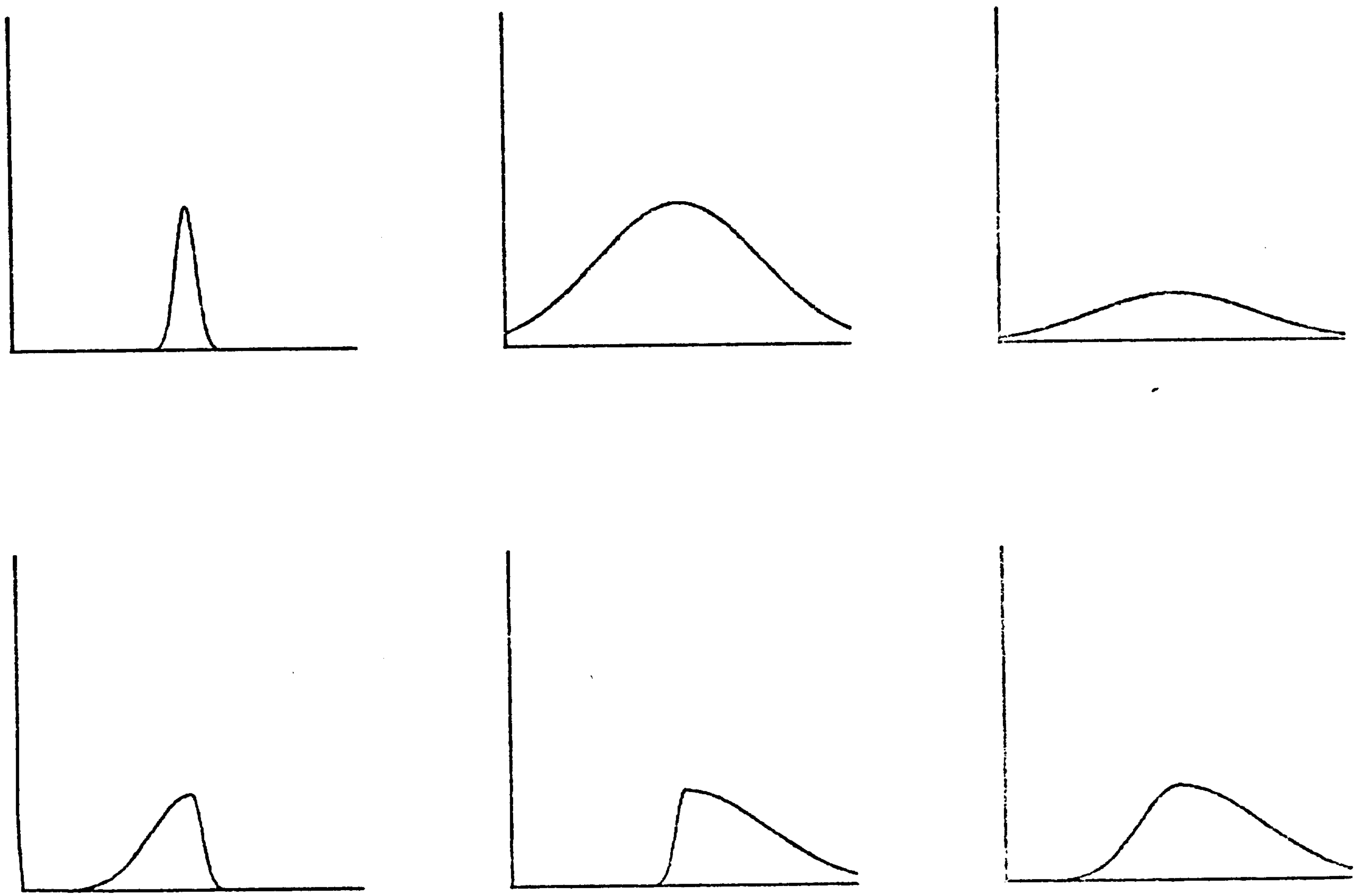
NEW MODEL - ADVANTAGES

- ALLOWS INDEPENDENT FITTING BEFORE AND AFTER PEAK, WHILE ENSURING CONTINUITY AT PEAK
  - LESS GLOBAL EFFECT OF LOCAL PHENOMENA
- GREATLY REDUCES IMPORTANCE OF OFFSET
  - T = 0 IS PEAK RATHER THAN START-UP (MORE STABLE AFTER SHIFT)
  - GREENNESS OFFSET STILL DESIRABLE, BUT REQUIRED PRECISION IS LOWER



NEW MODEL - METHOD OF FITTING
Fit to Early Observations
Greenness Values Over Time
Fit to Later Observations
Time of Peak Green
Day of Year
Greenness
70
25
125
215

NEW MODEL
EXAMPLES OF FLEXIBILITY

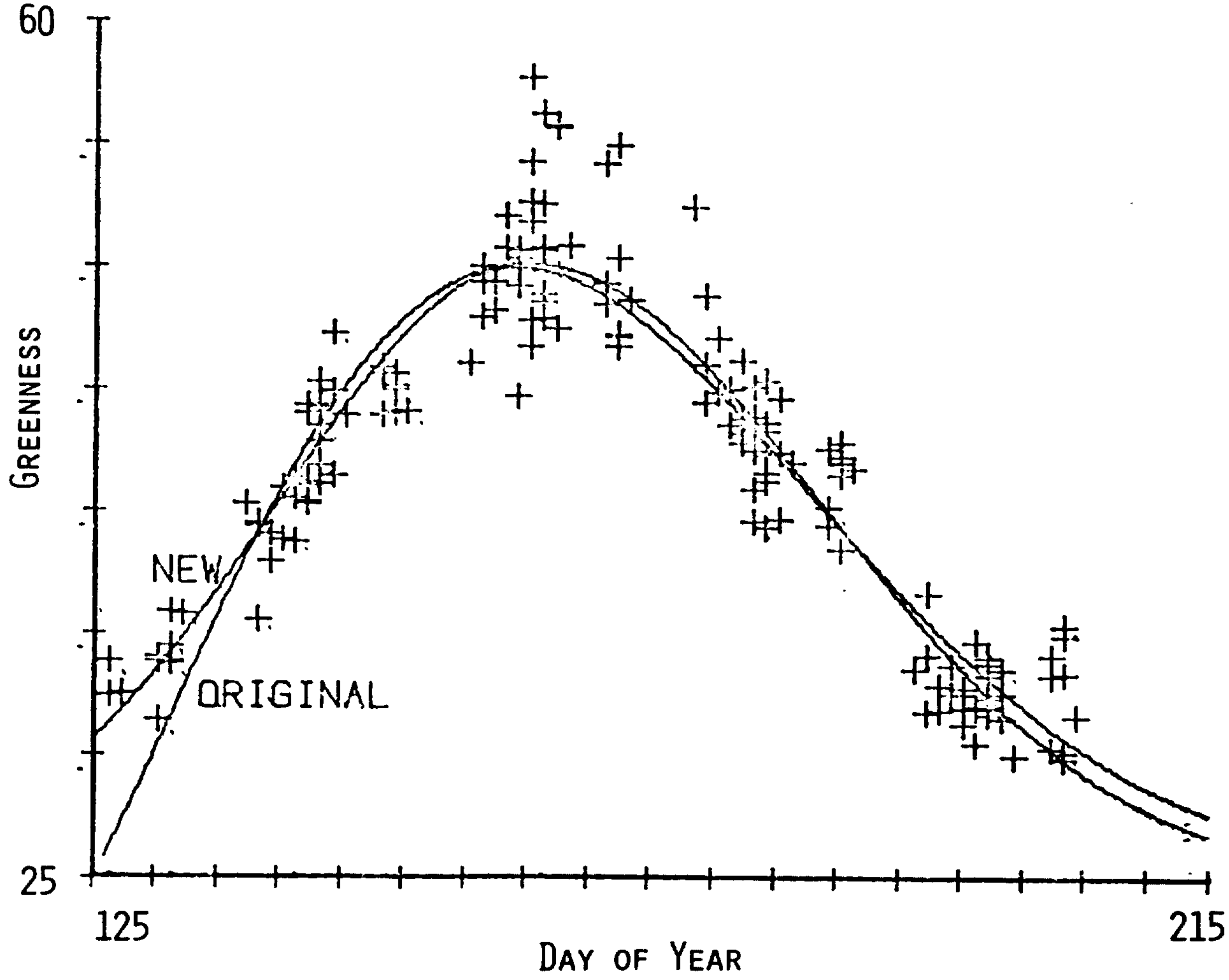


EVALUATION OF NEW MODEL

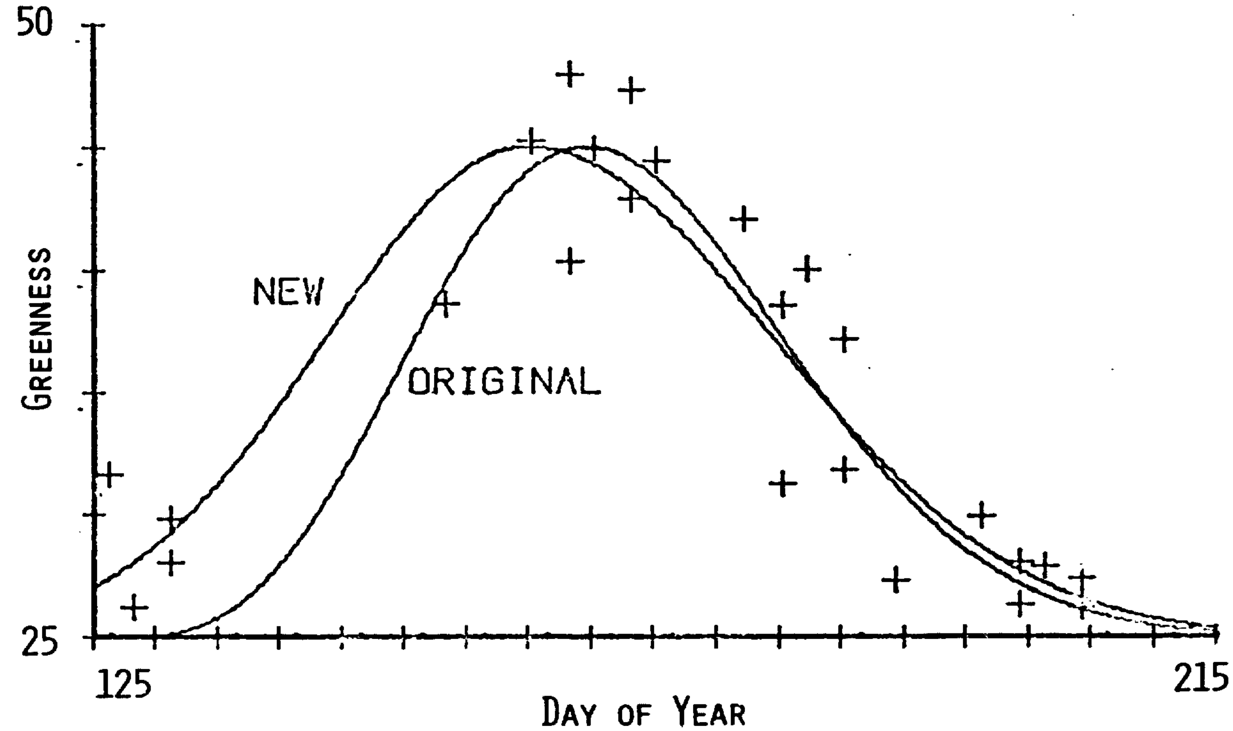
- FIT TO PIXEL AND FIELD MEAN DATA
  - BETTER IN MOST CASES
  - MODEL UNABLE TO FIT NEAR-LINEAR RISE IN A FEW FIELDS
- FIT TO TEST DATA - SIMULATED GREENNESS OBSERVATIONS OVER TIME
  - MORE FLEXIBLE, ADAPTABLE
  - LESS DEPENDENT ON ACCURATE OFFSET
- DEMONSTRATION OF FLEXIBILITY
  - SHOULD BE ABLE TO FIT ANY CROP WITH A SINGLE GREEN-UP PHASE

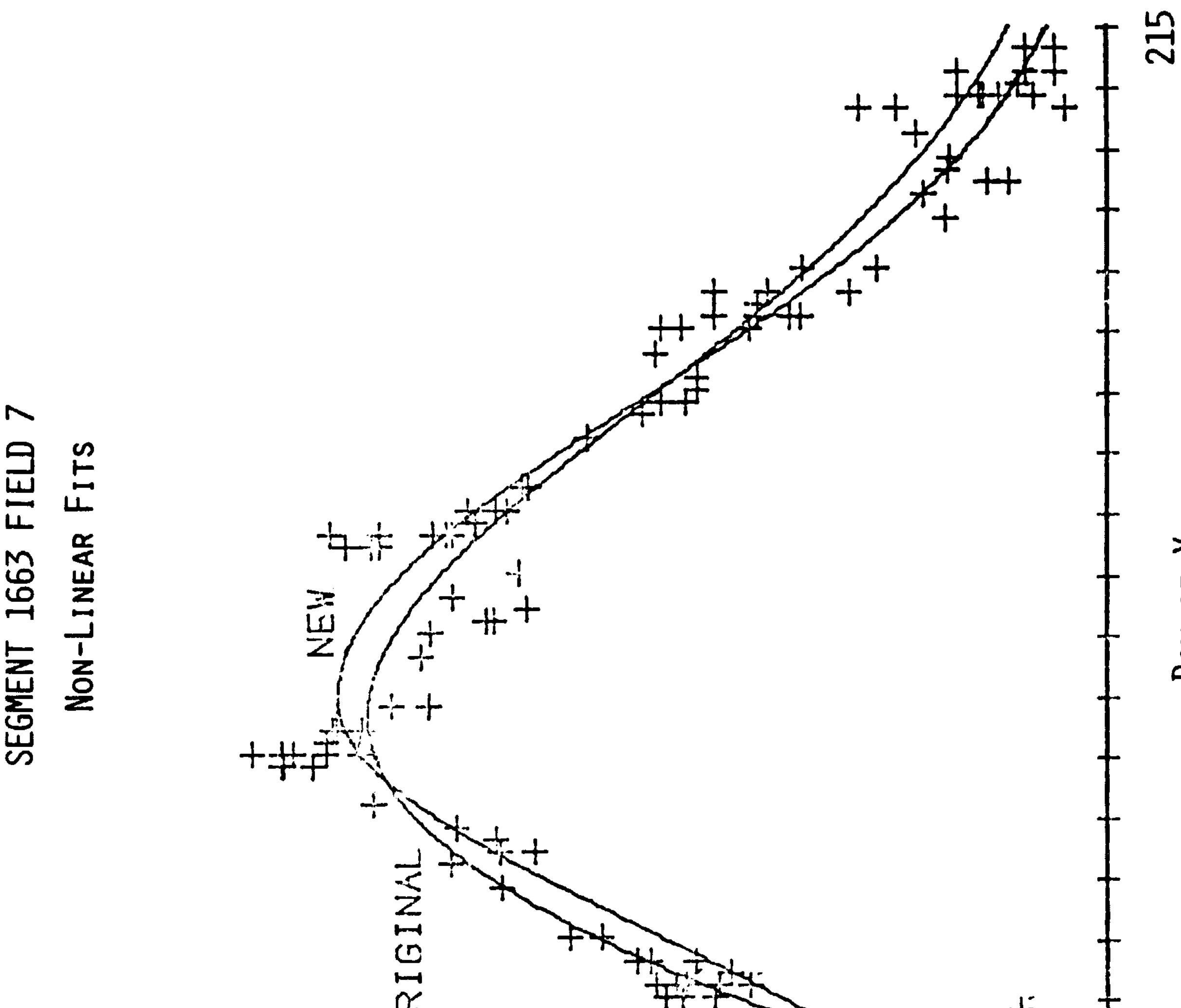
SEGMENT 1669 FIELD 30

NON-LINEAR FITS



SEGMENT 1929 FIELD 23
NON-LINEAR FITS




SEGMENT 1663 FIELD 7
NON-LINEAR FITS
NEW
ORIGINAL
GREENNESS
65
25
125
215
DAY OF YEAR

FITTING NEW MODEL TO FIELD DATA

Cost Estimates (Amdahl V7)

Data Set	Processing Time	Cost	Estimated Cost Without I/O
105 Observations (pixel data)	.43 to .54 seconds	15-20¢	6-12¢
5 Observations (field means)	.23 to .30 seconds	8-11¢	3¢

PROCEDURE FOR FITTING GREEN DEVELOPMENT PROFILE TO FIELD DATA

1. Preprocess
   - Satellite calibration
   - Sun angle correction
   - SCREEN out bad data, clouds, etc.
   - XSTAR haze correction (spatially varying)
2. Inset to eliminate boundary effects
3. Estimate crop calendar shift
4. Apply greenness offset of 25 counts
5. Estimate parameters of new model using non-linear least squares method

SUMMARY AND CONCLUSIONS

- THE VARIOUS APPLICATIONS OF PROFILES AND PROFILE-FITTING MAKE DIFFERENT DEMANDS IN TERMS OF ACCURACY
  - LEVEL 1 GENERALIZED FORM
  - LEVEL 2 EXTRACTION OF PARTICULAR FEATURE
  - LEVEL 3 CHARACTERIZATION OF OVERALL CROP DEVELOPMENT
  - LEVEL 4 SUBSTITUTION FOR MISSING DATA
- ORIGINAL MODEL AND PROCEDURE SUCCESSFULLY APPLIED AT LEVELS 1 AND 2
- LEVEL 3 APPLICATION APPEARS TO BE FEASIBLE, USING THE NEW MODEL FORM
- LEVEL 4 APPLICATION MAY BE POSSIBLE AT THE PRESENT TIME, BUT REQUIRES CONSIDERABLY MORE WORK
  - COMPILATION AND UNDERSTANDING OF HISTORICAL SPECTRAL DATA
  - THOROUGH UNDERSTANDING OF AGRONOMIC CHARACTERISTICS
- DATA NORMALIZATION AND PREPROCESSING ARE VITAL STEPS IN THE PROFILE-FITTING PROCESS

RECOMMENDATIONS

- USE THE DEFINED PROCEDURE IN APPLICATIONS OF PROFILE FITTING
- BEGIN CHARACTERIZATION OF PROFILES FOR OTHER CROPS
  - SINGLE GREEN-UP PHASE
  - MULTIPLE GREEN-UP PHASES
- BEGIN CONSIDERATION OF PROFILE FITTING GIVEN ONLY EARLY SEASON ACQUISITIONS
- CONTINUE STUDY OF OFFSETTING, ESTIMATION OF DATE OF FIRST DETECTABLE EMERGENCE
- CONSIDER PARAMETER ESTIMATION METHODS OTHER THAN LEAST SQUARES
  - B-SPLINES
- BEGIN WORK ON LEVEL 4 (DATA SUBSTITUTION) APPLICATION OF PROFILE TECHNOLOGY

CROP GROWTH STAGE ESTIMATION USING LANDSAT DATA

SEPTEMBER 1979

PRESENTED BY:

W. A. MALILA

OUTLINE

- PROBLEM STATEMENT
- OBJECTIVES
- APPROACH
- PROGRESS
- SUMMARY

PROBLEM STATEMENT

- UNCERTAINTIES ABOUT CROP GROWTH STAGES CONTRIBUTE TO AI LABELING ERRORS:
  - WITHIN SEGMENT (BETWEEN FIELDS)
  - BETWEEN SEGMENTS
- MISSING ACQUISITIONS COMPOUND THE PROBLEM
- A NEED EXISTS FOR AN OBJECTIVE CAPABILITY TO ESTIMATE THE CROP CALENDARS FOR:
  - INDIVIDUAL FIELDS OR QUASI-FIELDS
  - INDIVIDUAL PIXELS OR DOTS

OBJECTIVES

- LONG RANGE: TO DEVELOP AN OBJECTIVE METHOD FOR ESTIMATING THE CROP CALENDARS OF INDIVIDUAL FIELDS, USING MULTI-DATE LANDSAT DATA, FOR USE IN LABELING PROCEDURES.

- NEAR TERM: TO COMPARE SPECTRAL/TEMPORAL LANDSAT DATA WITH CORRESPONDING GROUND OBSERVATIONS OF WHEAT GROWTH STAGE.

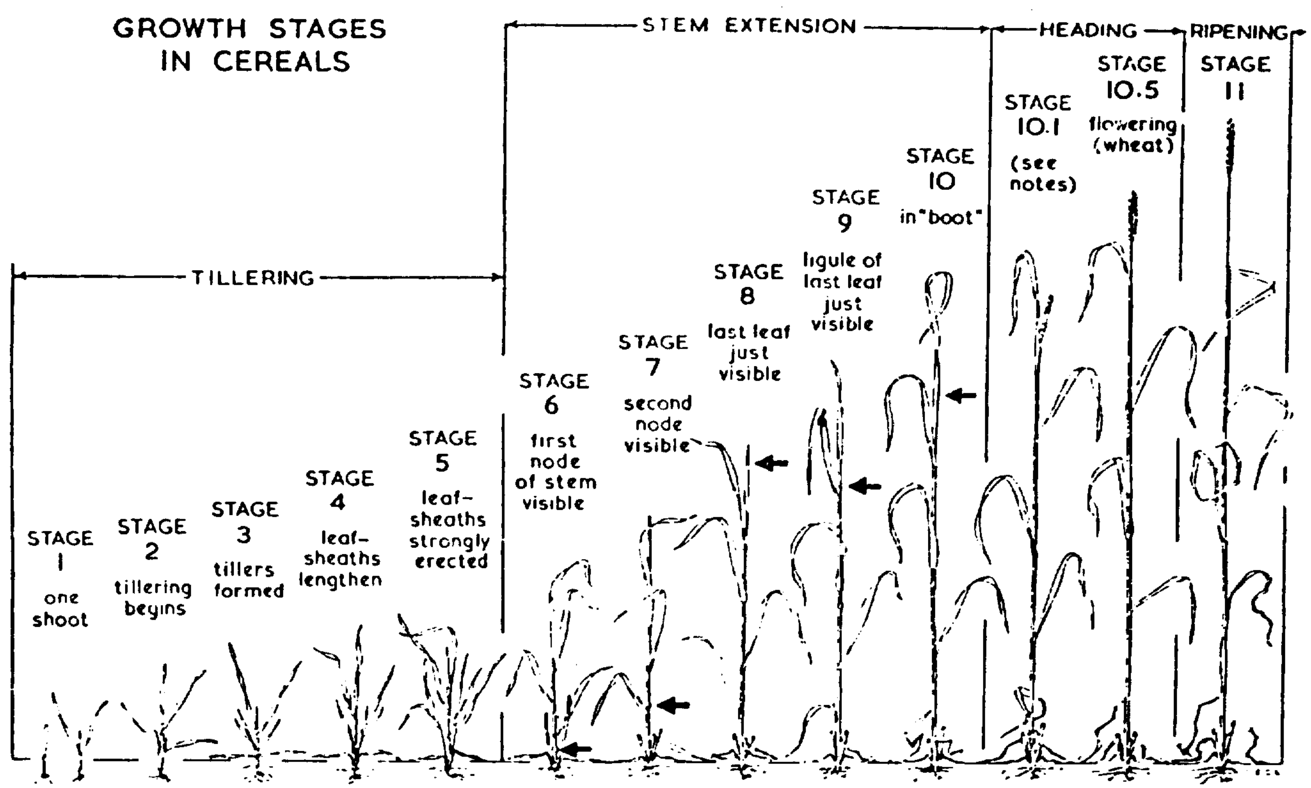
- LIMITATIONS IMPOSED ON THIS ANALYSIS:
  - END OF SEASON CONDITIONS APPLY (ALL AVAILABLE ACQUISITIONS)
  - FIELD IDENTITIES ARE GIVEN

- COMMENT: ULTIMATELY, WE ENVISION A CROP CALENDAR ESTIMATION METHODOLOGY THAT COMBINES METEOROLOGICAL AND SPECTRAL INPUTS.

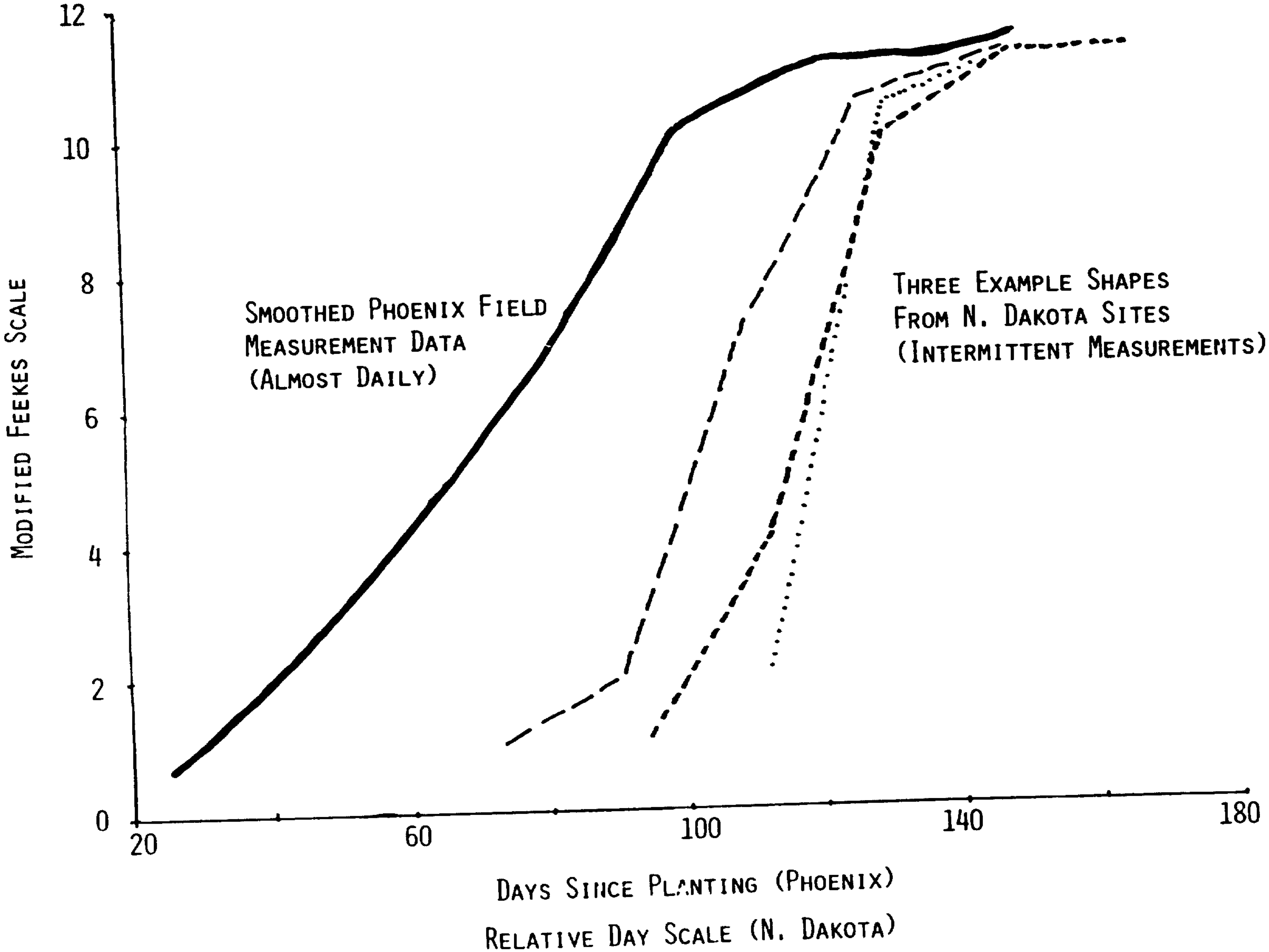
APPROACH

- CHOOSE LANDSAT FEATURES
  - CHOSE GREENNESS FOR THIS INITIAL WORK, BASED ON FIELD MEASUREMENT DATA AND OTHER STUDIES
  - APPLIED 'GREEN PROFILE SHIFT' TECHNOLOGY
- SELECT AND PREPARE A DATA SET
  - CHOSE 15-FIELD DATA FROM TY 1978 SPRING WHEAT BLIND SITES
  - PREPROCESSED TO COMPENSATE FOR NON-AGRONOMIC EFFECTS IN LANDSAT DATA
- COMPUTE LANDSAT FEATURES
- ANALYZE AND COMPARE WITH GROUND OBSERVATIONS
  - PLOTTED FEEKES SCALE VS. DAY AND SHIFTED DAY
  - INITIATED ANALYSIS

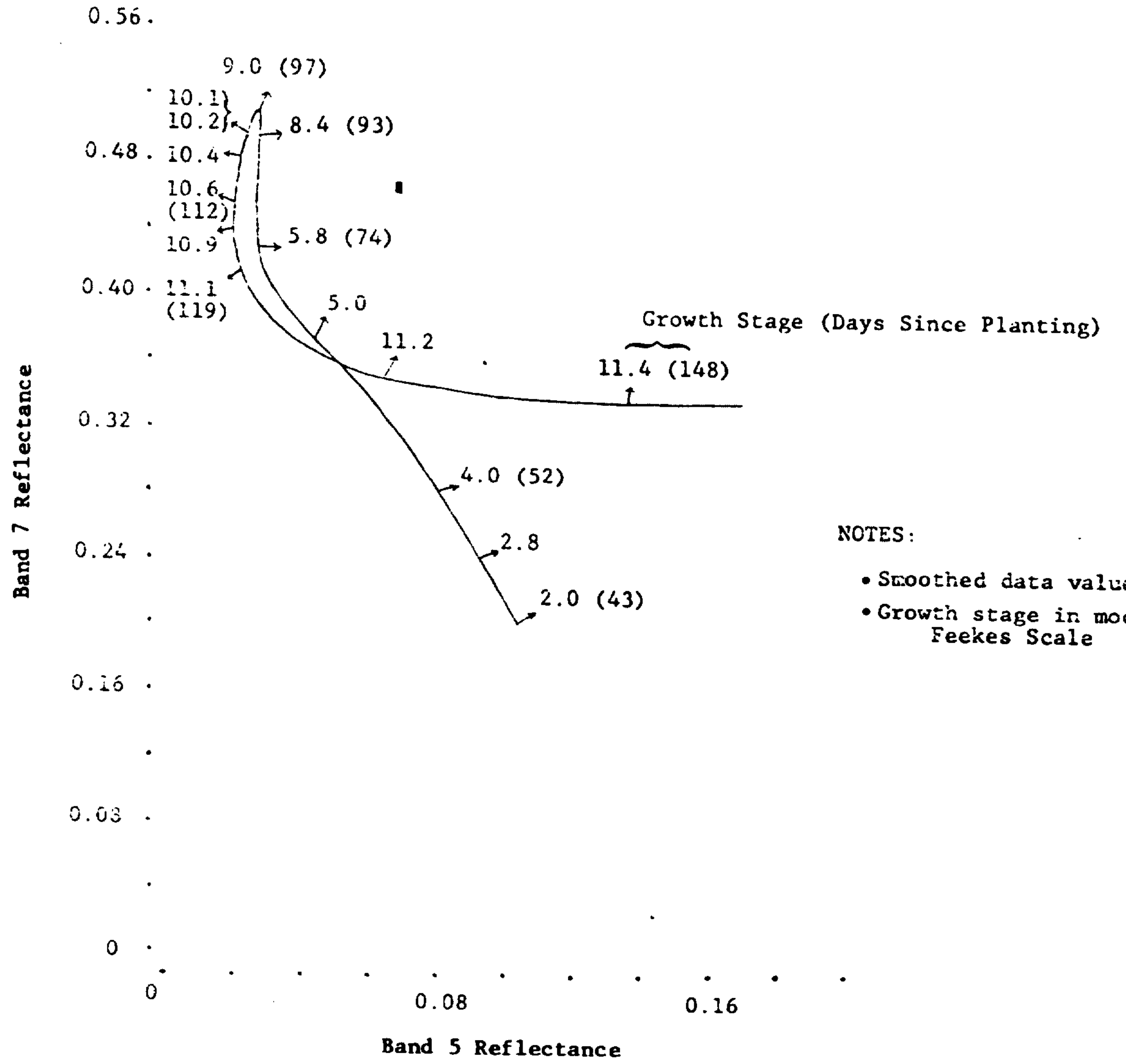
MODIFIED FEEKES SCALE



COMPARISON OF GROWTH STAGE TIME PROFILES



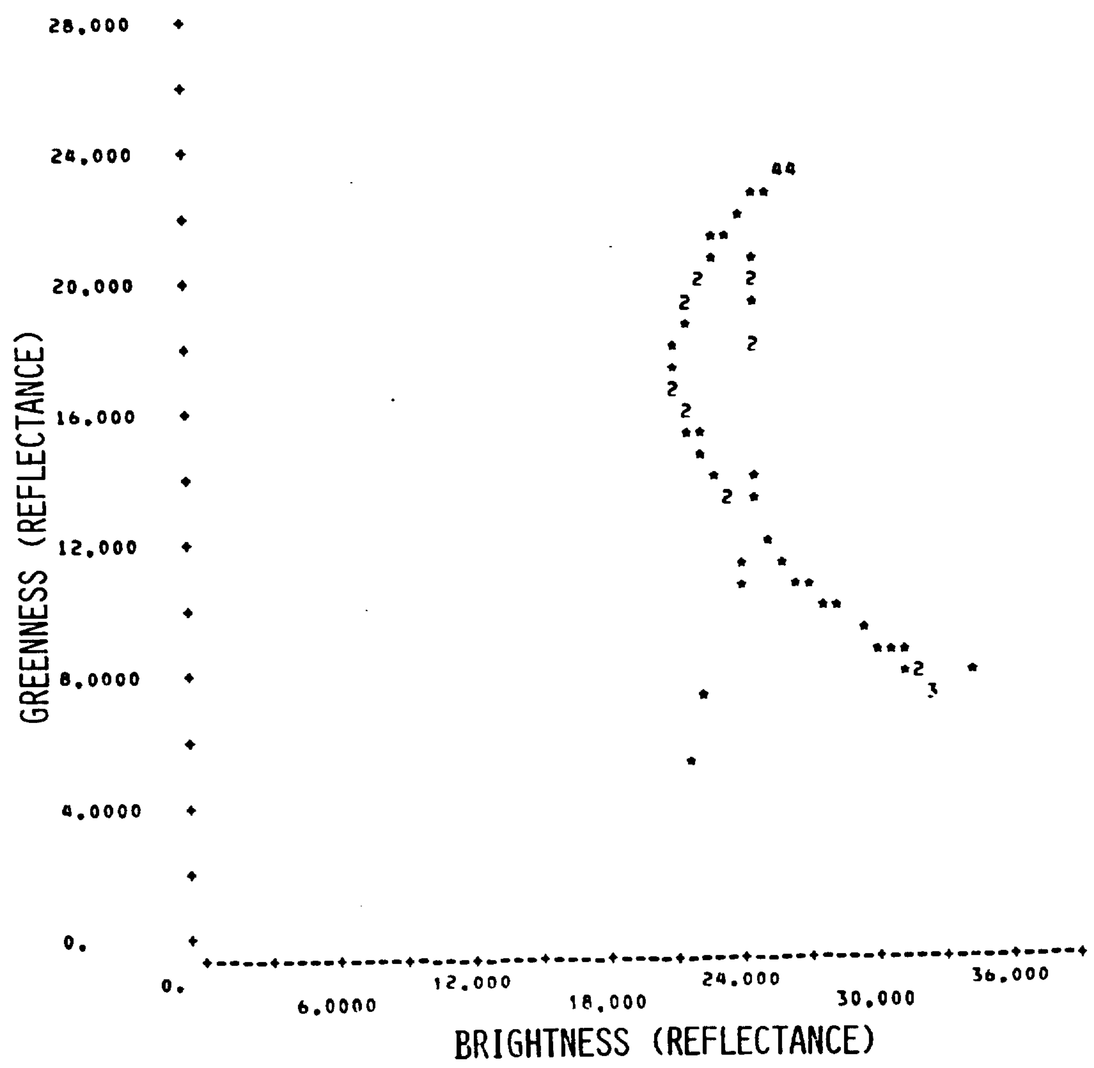
DEPENDENCE OF WHEAT SPECTRUM ON GROWTH STAGE AND DAYS SINCE PLANTING (PLOT 6A, DRY TREATMENT)



NOTES:

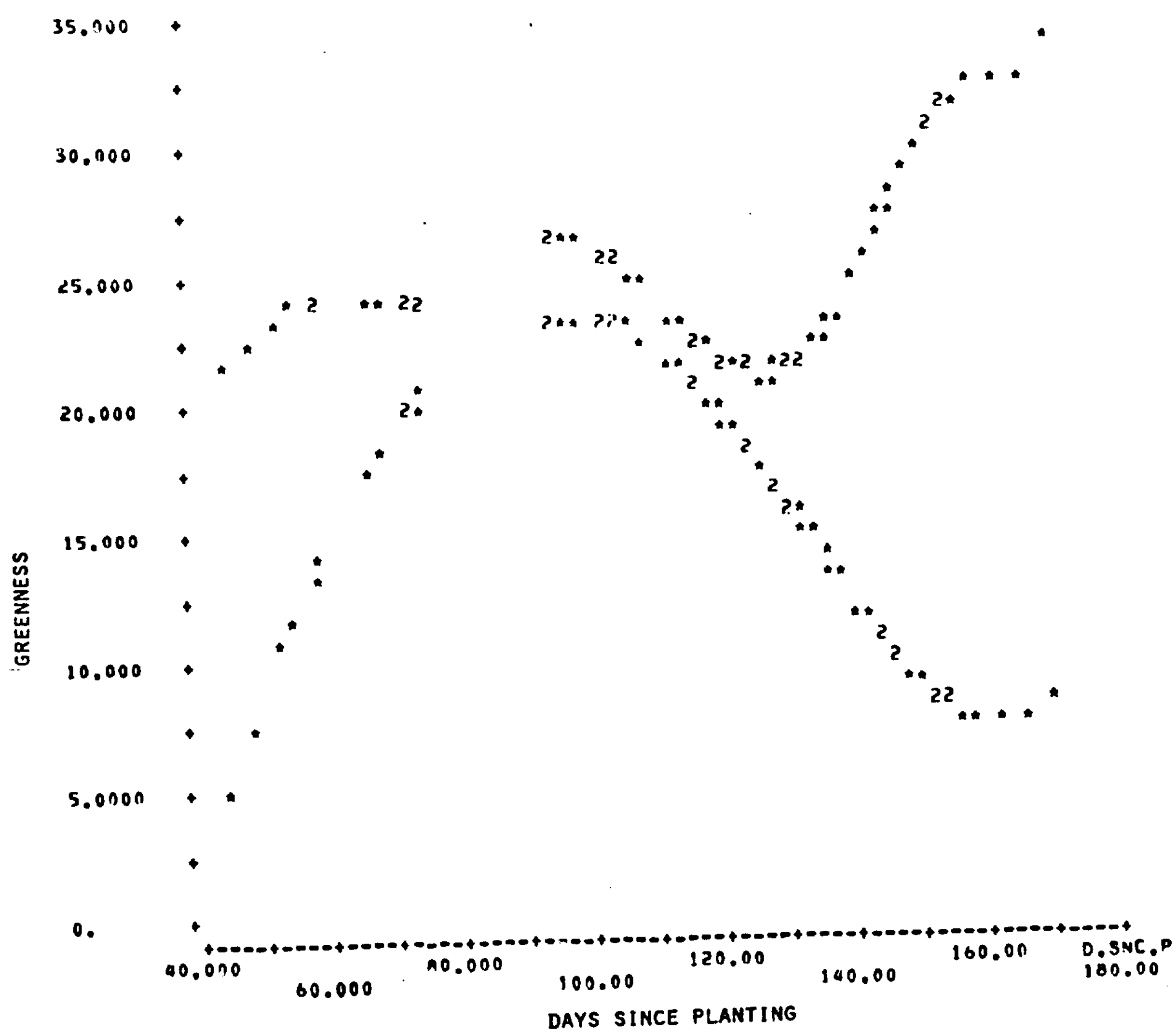
- Smoothed data values
- Growth stage in modified Feekes Scale

TASSELED-CAP-EQUIVALENT SPECTRAL TRAJECTORY
(PLOT 6A, DRY TREATMENT)



SMOOTHED TIME PROFILE OF GREENNESS

(PLOT 6A, DRY TREATMENT)



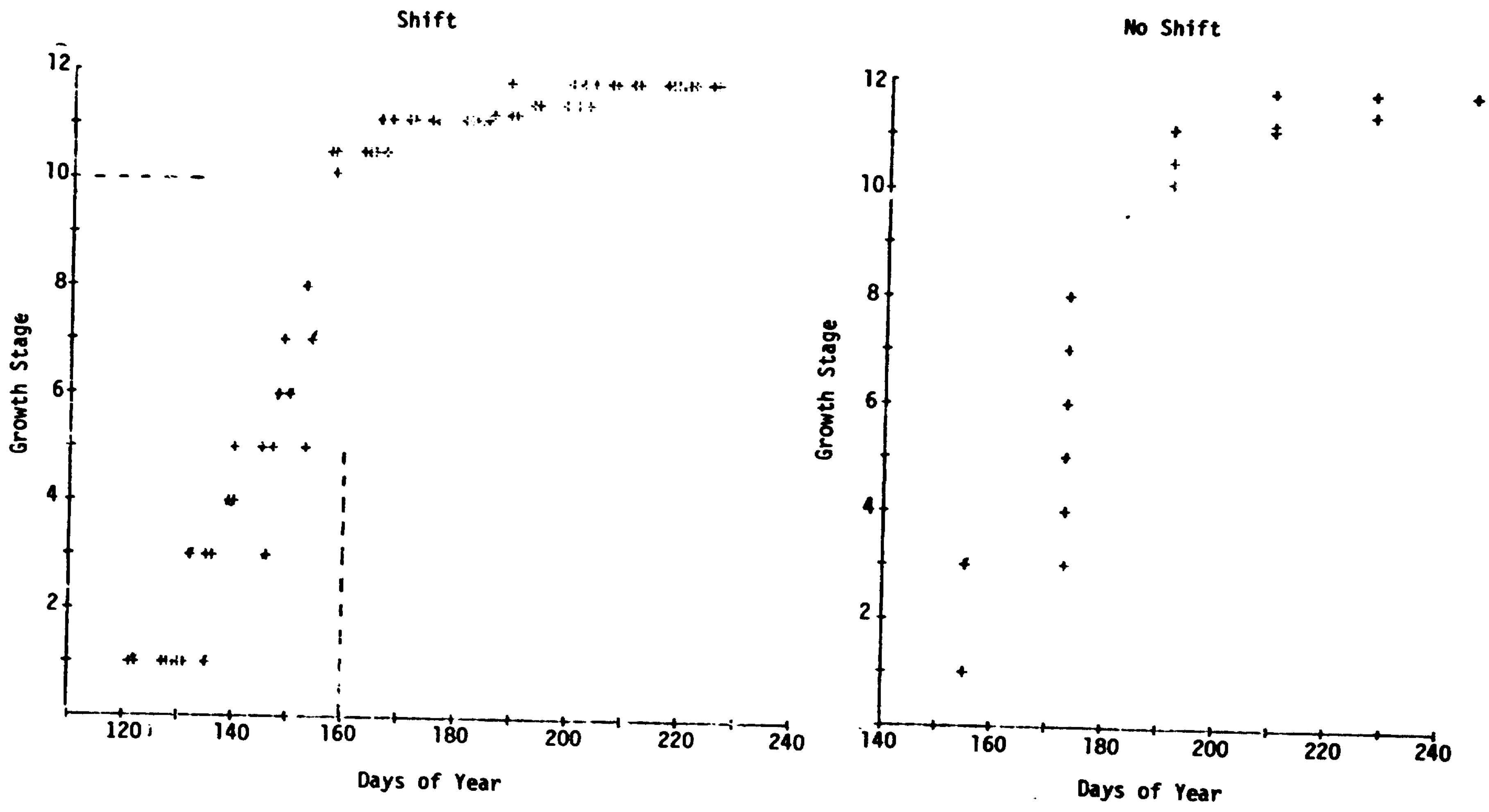
GREEN PROFILE SHIFT TECHNOLOGY

- CHARACTERISTICS:
  - USES REFERENCE SMALL-GRAIN PROFILE OF GREENNESS VS. DAY OF YEAR
  - CALCULATES DAY SHIFT BETWEEN SUBJECT AND REFERENCE PROFILE
- ESTIMATION OF SHIFT, E.G., DATE OF PEAK GREENNESS (LEVEL 1 APPLICATION):
  - PEAK OCCURS JUST PRIOR TO HEADING
  - GROWTH STAGE 9 TO 10 ON MODIFIED FEEKES SCALE (FIELD MEASUREMENTS)
- LATER CROP STAGE ESTIMATION MAY REQUIRE MORE COMPLETE CHARACTERIZATION OF PROFILES (LEVEL 2 AND/OR 3 APPLICATION)

EFFECT OF DAY SHIFT ON GROWTH STAGE PROFILES

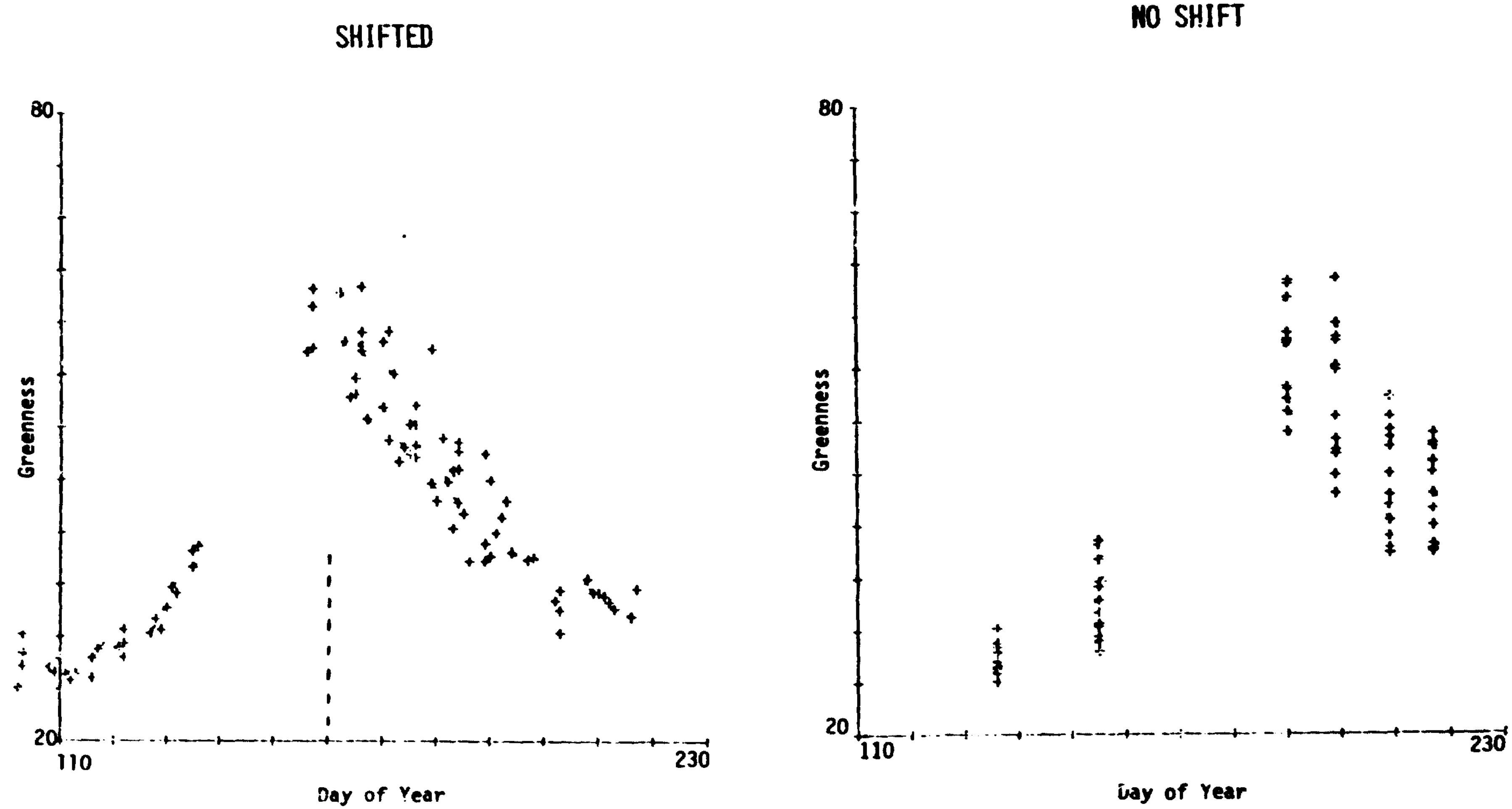
(Type 1)

Segment 1461



EFFECT OF DAY SHIFT ON LANDSAT GREENNESS PROFILES

SEGMENT 1461



DATA SET

Subset of TY 1978 Spring Wheat Blind Sites

Landsat Data (Both Landsat 2 and 3)

Segment	Acquisitions	No. Fields	Range of Shift (Days)
1392	136, 154, 190, 208, 217	12	-27 to -18
1457	156, 174, 228, 246, 264, 273	13	-73 to -35
1461	136, 155, 190, 199, 209, 217, 236	13	-34 to -19
1636	135, 154, 190, 208, 216, 226, 243	12	-47 to -10

DATA SET (CONT.)

- GROUND OBSERVATIONS OF CROP DEVELOPMENT
  - APPROXIMATELY 18-DAY INTERVALS, KEYED TO LANDSAT 2
  - MEASURED AGAINST MODIFIED FEEKES SCALE
- LANDSAT PREPROCESSING TO COMPENSATE FOR NON-AGRONOMIC EFFECTS
  - SCREEN FOR BAD DATA, CLOUDS, ETC.
  - CALIBRATION ADJUSTMENTS FOR LANDSAT 2 AND 3
  - SUN ANGLE CORRECTION
  - HAZE CORRECTION USING SPATIALLY VARYING XSTAR
  - FIELD INTERIOR PIXELS ONLY
- FEATURE COMPUTATION
  - DAY SHIFT CALCULATED USING SPECTRAL MEANS OF INTERIOR PIXELS

SUMMARY

- A STUDY OF WHEAT GROWTH STAGE ESTIMATION USING LANDSAT DATA IS UNDERWAY
- ISSUES:
  - CHARACTERIZATION OF FEEKES PROFILE WITH ~18-DAY INTERVAL ON OBSERVATIONS
  - SPARSENESS OF DATA
- POTENTIAL EXPANSIONS:
  - USE OF OTHER SPECTRAL FEATURES, E.G., BRIGHTNESS

CONSIDERATIONS IN
CROP INVENTORY SYSTEM DESIGN

SEPTEMBER 1979

PRESENTED BY:

RICHARD J. KAUTH

CONSIDERATIONS IN
CROP INVENTORY SYSTEM DESIGN

- PREAMBLE
- SYSTEM OUTPUTS
- EVALUATION FACTORS
- CRITICAL DESIGN ISSUES
- TESTING

PREAMBLE

- INVENTORY SYSTEM IS BASED ON REMOTELY SENSED DATA
  - DOES NOT INCORPORATE HIGHER LEVEL REPORTS (USER GENERATED) AS COLLATERAL DATA
  - INTERFACE TO THOSE DATA IS USER RESPONSIBILITY

- DISTINCTION BETWEEN INVENTORY SYSTEM AND PILOT TEST SYSTEM
  - INVENTORY SYSTEM GENERICALLY DEFINED
  - PILOT TEST ESTIMATES PERFORMANCE PROFILES FOR INVENTORY SYSTEM

SYSTEM OUTPUTS

- REGULAR (PERIODIC) OUTPUTS
  - MULTICROP AREA/YIELD/PRODUCTION AT POLITICAL SUBDIVISION LEVEL
  - INTERCROP COVARIANCE ESTIMATES FOR ABOVE
  - STATEMENT OF CONFIDENCE INTERVALS FOR ABOVE
  - GENERAL CROP CONDITION ASSESSMENT

- DEMAND OUTPUTS
  - INTENSIVE LOCAL OR REGIONAL ANALYSIS OF AREA/ YIELD/PRODUCTION
  - EPISOIDAL EVENTS

EVALUATION FACTORS

- ACCURACY
  - BIAS
  - COVARIANCE
- TIMELINESS
  - AGE OF DATA FOR REGULAR ESTIMATES
  - THROUGHPUT TIME FOR REGULAR ESTIMATES
  - RESPONSE TIME FOR DEMAND ESTIMATES
- DEGREE TO WHICH SYSTEM SUPPORTS/SUPPLEMENTS HIGHER LEVEL USER SYSTEM
- COST

DESIGN CONSIDERATIONS

- GESTALT OF DESIRED INVENTORY SYSTEM (8-10 YEARS)
- SHORTER TERM PHASED DEVELOPMENT (P1A/P2)
- CRITICAL DESIGN ISSUES

SOME CHARACTERISTICS OF A FUTURE IDEALIZED CROP INVENTORY SYSTEM

A. STRATIFICATION

1. DYNAMIC VS STATIC ASPECTS
    - STATIC: SOILS, CLIMATE, AG/NON-AG (ALLOWING FOR NEW LANDS POTENTIAL), LANDSAT INPUTS
    - DYNAMIC: LANDSAT, METSAT (CURRENT-YEAR WEATHER) (INFLUENCED BY CROP CONDITIONS)
2. BETTER USE OF STRATIFICATION VARIABLES
    - CONTINUOUS VS DISCRETE
    - DISJOINT VS CONTIGUOUS
    - AGGREGATION VS MEASUREMENT
    - WITHIN AG: FIELD SIZE VS RESOLUTION
3. STRATIFIER USING A 'COARSE' CLASSIFIER OR ESTIMATOR (BASED ON SIGNATURE INFORMATION)

SOME CHARACTERISTICS OF A FUTURE IDEALIZED CROP INVENTORY SYSTEM (CONT.)

B. SAMPLING STRATEGY

1. SAMPLING FRAME/SEGMENT SIZE/SEGMENT LOCATION/SEGMENT FORM/ DYNAMIC
2. MULTISTAGE SAMPLING/MULTISENSOR
3. MULTIYEAR SAMPLING
4. MULTIPURPOSE SAMPLING

SOME CHARACTERISTICS OF A FUTURE IDEALIZED CROP INVENTORY SYSTEM (CONT.)

C. PREPROCESSING

1. IMPROVED CORRECTIONS FOR EXTERNAL EFFECTS (SCAN ANGLE) (TM BANDS)
2. IMPROVED SPATIAL REGISTRATION

SOME CHARACTERISTICS OF A FUTURE IDEALIZED CROP INVENTORY SYSTEM (CONT.)

D. FEATURE EXTRACTION

1. TASSELED-CAP ANALOG FOR THEMATIC MAPPER
2. SPECTRAL/TEMPORAL/AGRONOMIC FEATURES
3. PURE VS MIXED PIXELS/FIELD STRUCTURE
4. CHARACTERIZATION OF COLLATERAL INFORMATION IN SIMPLIFIED FORMAT

SOME CHARACTERISTICS OF A FUTURE IDEALIZED CROP INVENTORY SYSTEM (CONT.)

E. ESTIMATION PROCEDURE

1. SIGNATURE CHARACTERIZATION
2. DIRECT CROP PROPORTION ESTIMATES
3. OBJECTIVE LABELING
4. PROPORTIONAL AND/OR PROBABILISTIC LABELING
5. MISSING SEGMENT/ACQUISITION PROBLEMS
6. ANALYST ROLE: INSIGHT, COLLATERAL INFORMATION, SUPERVISION

SOME CHARACTERISTICS OF A FUTURE IDEALIZED CROP INVENTORY SYSTEM (CONT.)

F. AGGREGATION/OUTPUTS

1. REGULAR VS DEMAND
2. OBJECTIVE VS QUALITATIVE
3. AGGREGATION TO VARIOUS LEVELS

CONTINUED DEVELOPMENT OF STRATIFICATION AND SAMPLING TECHNIQUES

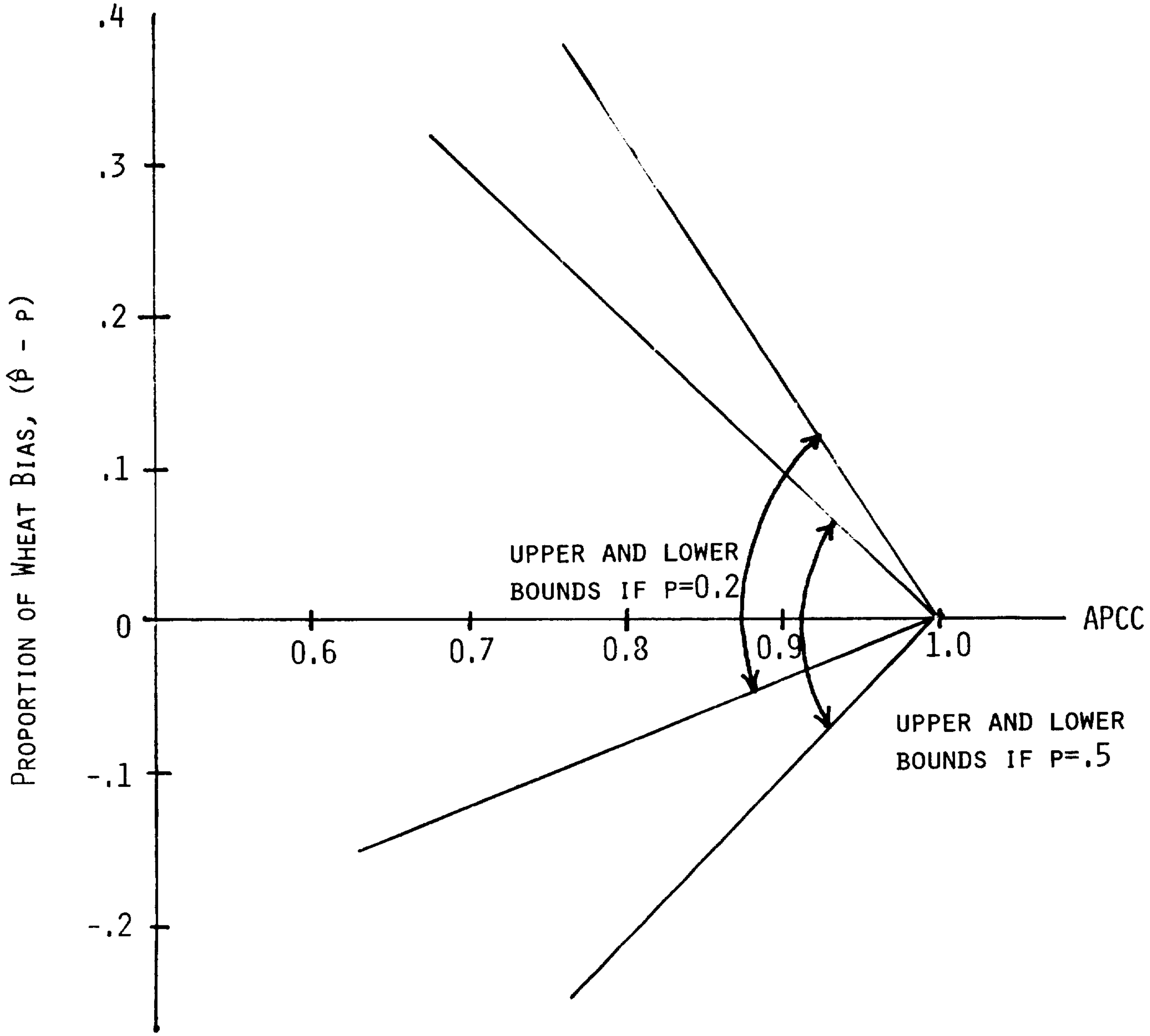
- PURPOSES: REDUCE VARIANCE, BIAS, RMS ERROR
- LEVELS:
  - LABELING TARGETS WITHIN SPECTRAL STRATA
  - SEGMENTS FROM AREA OR YIELD STRATA
- SAMPLING DIRECTED TO:
  - SIZE OF STRATA
  - PRIORS (EXPECTED PURITY) OF STRATA
  - ERRORS (EXPECTED TYPE 1 AND TYPE 2 ERRORS) OF STRATA
- STRATIFICATION:
  - PRIOR TO SAMPLING
  - POSTERIOR TO SAMPLING
- PERFORMANCE MODEL IS BASIS FOR FUTURE DEVELOPMENTS

CONSIDERATIONS REGARDING ACCURACY (I.E., BIAS) FOR CLASSIFIERS

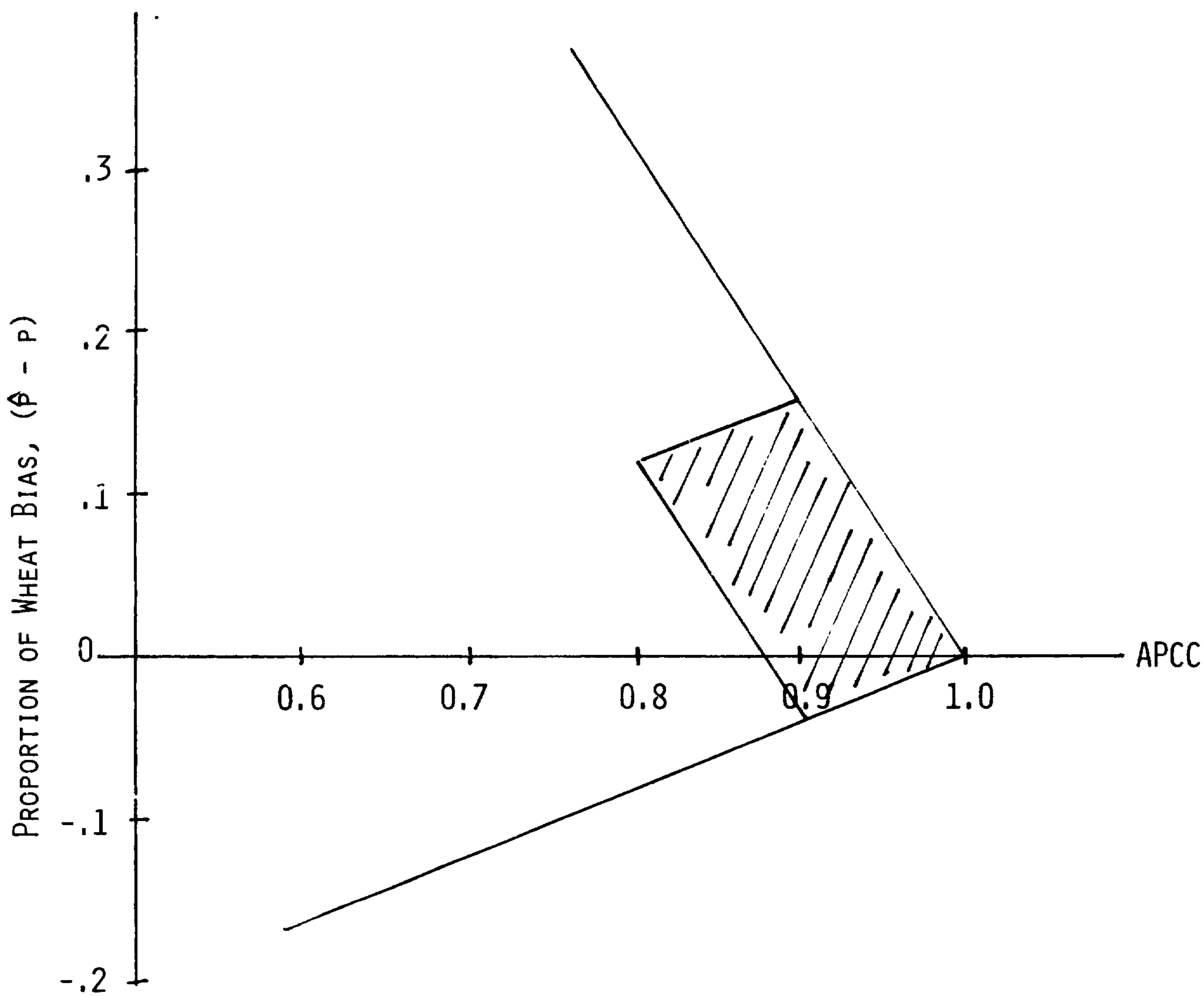
- UNKNOWN BIAS OF A CONSISTENT CLASSIFIER IS POTENTIALLY A SERIOUS PROBLEM. FOR EXAMPLE, A CLASSIFIER WITH AN AVERAGE PROBABILITY OF CORRECT CLASSIFICATION OF 0.9 HAS A POTENTIAL RELATIVE BIAS OF 80% IF THE TRUE PROPORTION IS .2. (SEE NEXT 2 SLIDES.)

- VARIANCE REDUCTION FACTORS OBSERVED IN BOTH P1 AND PROCEDURE M TESTS SUGGEST THAT BASIC SEPARABILITY OF SMALL GRAINS DOES NOT ALLOW BETTER THAN A .9 CLASSIFIER. (SEE THIRD SLIDE, FOLLOWING.)

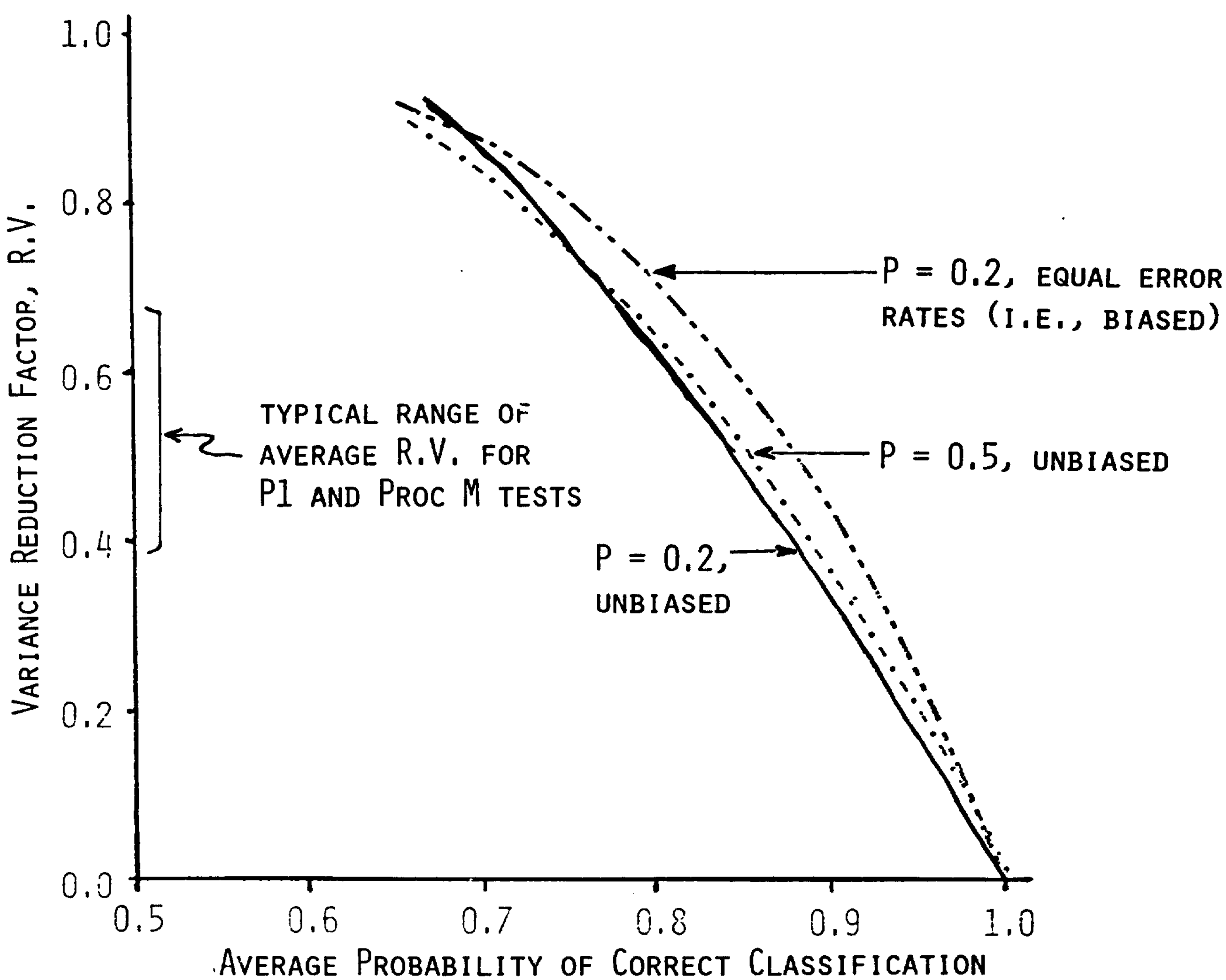
POTENTIAL BIAS OF A CLASSIFIER
WHEN ALL THAT IS KNOWN IS THE
AVERAGE CONDITIONAL PROBABILITY OF CORRECT CLASSIFICATION (APCC)



POTENTIAL BIAS OF A CLASSIFIER WHEN TYPE 1 AND TYPE 2 ERRORS ARE INDIVIDUALLY BOUNDED BETWEEN 0.0 AND 0.2, FOR P = .2



VARIANCE REDUCTION FACTOR FOR SEVERAL CLASSIFIERS WHEN THE TRUE PROPORTION OF WHEAT IS P



CONSIDERATIONS REGARDING ACCURACY FOR CLASSIFIERS (CONT.)

POSSIBILITIES TO REMOVE EFFECTS OF LARGE POTENTIAL BIAS:

- GROUND TRUTH PROPORTION FOR A SAMPLING OF SITES
  - LARGE NUMBER OF SITES NEEDED TO ESTIMATE BIAS GIVEN LARGE VARIANCE OF ESTIMATES
- ESTIMATE LABELING ERROR RATE DISTRIBUTIONS (TYPE 1 AND TYPE 2) AS A FUNCTION OF COLLATERAL INFORMATION AT BOTH SEGMENT AND LABELING TARGET LEVEL. USE CONFUSION MATRIX TO DEBIAS ESTIMATES.
- ESTIMATE SIGNATURES AS A FUNCTION OF COLLATERAL INFORMATION AT SEGMENT AND LABELING TARGET LEVEL. USE MAXIMUM LIKELIHOOD OR CONDITIONAL EXPECTATION TO ESTIMATE PROPORTIONS.

ANALYST INTERPRETERS AS CLASSIFIERS

- THE ABOVE DISCUSSION APPLIES TO ANY CONSISTENT CLASSIFIER, AND WOULD CAST SERIOUS DOUBT ON ANY ANALYST-BASED SYSTEM, SINCE LACIE EXPERIENCE SUGGESTS CLASSIFICATION ACCURACY IN THE .8 TO .9 RANGE.

- HOWEVER, IT IS ESSENTIAL TO RECOGNIZE THAT THE HUMAN INTERPRETER MIGHT NOT ACTUALLY USE A CONSISTENT ASSIGNMENT RULE IN CASES WHERE HIS INTERNAL SIGNATURES OVERLAP. BY USING INCONSISTENT ASSIGNMENTS WHEN FORCED TO MAKE DECISIONS, THE AI COULD SIGNIFICANTLY DEBIAS THE SYSTEM.

SOME POSSIBLE MODELS TO EXPLAIN INCONSISTENT AI CLASSIFICATION

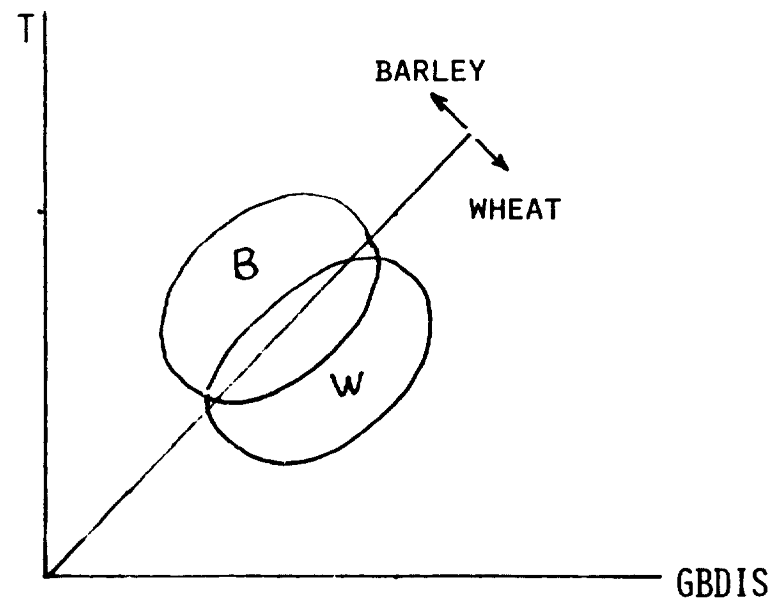
- RANDOM ASSIGNMENT DEPENDING ON PRIORS DEFINED BY THE LIKELIHOOD RATIO OF INTERNAL SIGNATURES.
- ASSIGNMENT TO THE CLASS OF A RANDOMLY CHOSEN, NEARBY TRAINING EXAMPLE.
- RE-ESTABLISHMENT OF DECISION BOUNDARIES BASED ON A FRESH SELECTION OF RECALLED TRAINING EXAMPLES, EACH TIME A CHANGED SITUATION OCCURS (E.G., MOVING TO A NEW SEGMENT).
- ANY OF THESE MODELS RESULTS IN REDUCED BIAS BUT HIGHER ERROR RATES THAN A CONSISTENT CLASSIFIER USING THE SAME BASIC INFORMATION.

RELATIONSHIP OF SIGNATURES TO PHYSICAL THEORY-BASED CLASSIFICATION SCHEME

- PHYSICAL UNDERSTANDING IS ONE ROUTE TOWARDS DEFINING A POTENTIALLY USEFUL FEATURE SET UPON WHICH TO BUILD SIGNATURES.
- EXAMPLE: PROCEDURE M SPRING WHEAT/BARLEY CONFIGURATION
  - THRESHOLD, T, IS A FUNCTION OF THE SPECTRAL OBSERVATIONS, AFTER A SERIES OF OPERATIONS (SHIFTING DAYS BASED ON GREENNESS PROFILE) WHOSE RATIONALE IS BASED ON PHYSICAL MODELING AND EMPIRICAL FITTING.
  - GREENNESS-BRIGHTNESS DISTANCE, GBDIS, IS A DIRECT FUNTION OF THE OBSERVATIONS.

RELATIONSHIP OF SIGNATURES TO PHYSICAL THEORY-BASED CLASSIFICATION SCHEME (CONT.)

- THESE FEATURES USED AS A CLASSIFIER LEAD TO CLASSIFICATION ACCURACIES RANGING FROM .60 TO .85. THE CLASSIFICATION RULE IS



IF GBDIS IS GREATER THAN T, CLASSIFY AS BARLEY.

- THESE SAME FEATURES CAN BE USED TO PRODUCE A MAXIMUM LIKELIHOOD PROPORTION ESTIMATE BY FIRST CHARACTERIZING THE TWO-DIMENSIONAL P.D.F. FOR WHEAT AND BARLEY.

COMPARISON OF ANALYST/MACHINE ROLES

- ROLE OF RESOURCE ANALYST
  - DEVELOP INITIAL STRATIFICATION AND CLASSIFICATION STRATEGIES
  - SERVE AS EXPERIMENTAL SUBJECT:
    + IDENTIFY THOSE FACTORS WHICH INFLUENCE ERROR RATES AND CONFUSION
    + IDENTIFY USEFUL COLLATERAL INFORMATION
  - PROVIDE FEATURES NOT ACCESSIBLE BY MACHINE PROCESSING
- ROLE OF MACHINE LABELING
  - IF GOOD SEPARATION
    + PROVIDE LABELS TO BE AGGREGATED

      OR

    + EXHAUSTIVE LABELS FOR SCENE
  - IF POOR SEPARATION (I.E., $\leq$ 90% CORRECT CLASSIFICATION AVAILABLE):
    + PROVIDE UNBIASED PROPORTION ESTIMATE BASED ON ACCURATE SIGNATURES ON THE FEATURE SPACE OF THE LABELER

POSSIBLE FUTURE RESOURCE ANALYST ROLES

- EVALUATE SUFFICIENCY OF SAMPLING AT REGIONAL LEVEL TO MEET PARTICULAR INFORMATION DEMANDS
- LAY ON REQUEST FOR ADDITIONAL SAMPLING
- EVALUATE SUFFICIENCY OF COLLATERAL DATA BASE FOR REGIONAL ESTIMATE
- ANALYZE AT REGIONAL AND LOCAL LEVEL TO ESTIMATE AND INPUT COLLATERAL DATA
- EVALUATE SUFFICIENCY OF GROUND TRUTH DATA FOR SIGNATURE UPDATE
- EVALUATE AND QUALIFY SEGMENT AND REGIONAL ESTIMATES
- EVALUATE SUFFICIENCY OF SAMPLING AT REGIONAL LEVEL

PERFORMANCE MODELING

- NEEDS TO ACCOMPANY EACH ASPECT OF SYSTEM DEVELOPMENT
- MAJOR ASPECTS: SAMPLING AND MEASUREMENT
- SUPPORTS SAMPLING DESIGN
- SUPPORTS COMPONENT DEVELOPMENT TEST AND EVALUATION
- SUPPORTS PILOT TEST DESIGN
- SUPPORTS PILOT TEST EVALUATION (ACCURACY ASSESSMENT)

REGISTRATION

ISSUES

- IMAGE-TO-GROUND VERSUS IMAGE-TO-IMAGE
- FULL FRAME VERSUS SEGMENT

IMPACTS

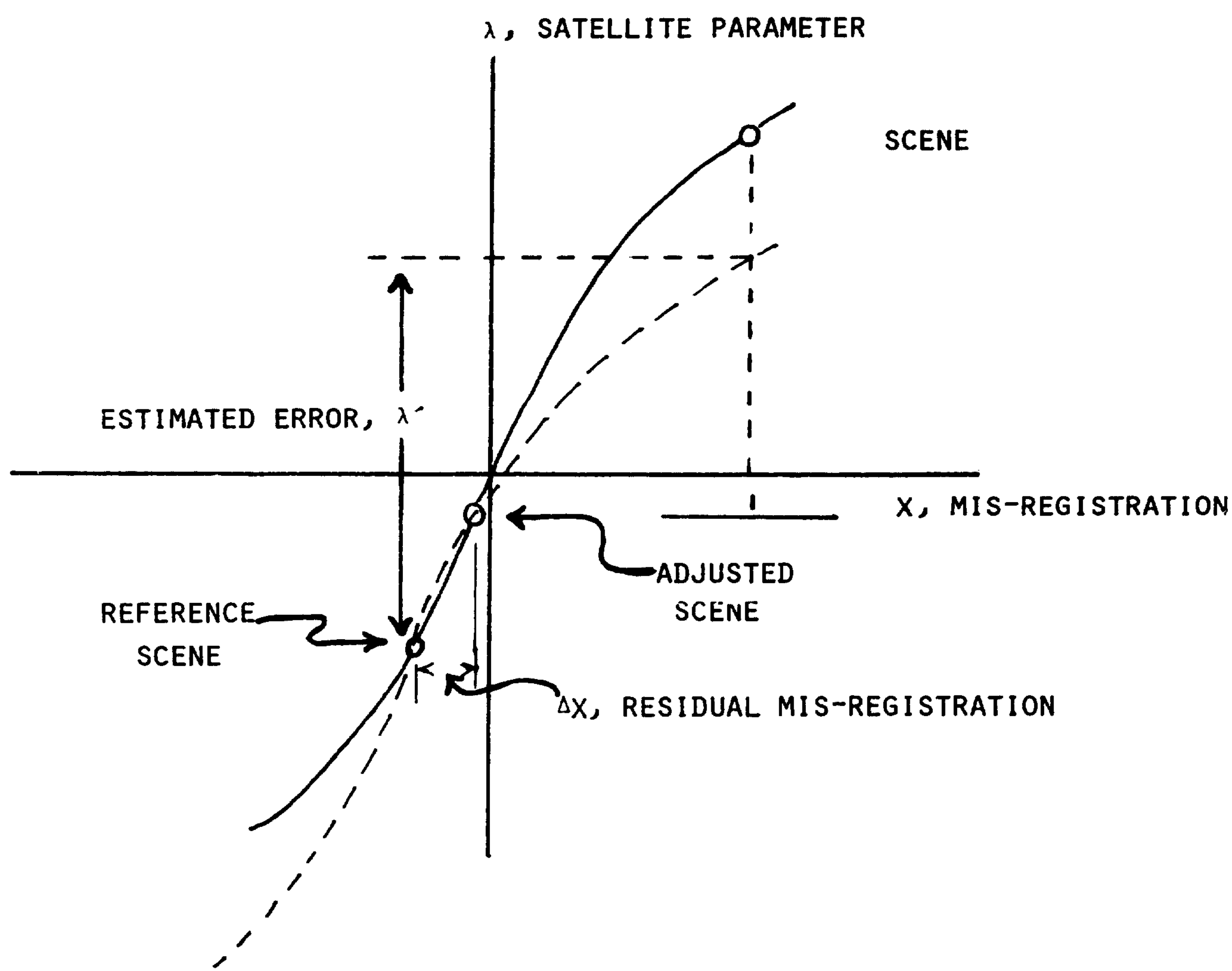
- FLEXIBLE SAMPLING STRATEGY
- SMALL FIELD LABELING ACCURACY
- MIXED PIXEL/TRASH PIXEL DOMINANCE

APPROACH - TWO-STAGE REGISTRATION AND RETRIEVAL SYSTEM

- ESTABLISH FULL FRAME MAPPING TO REFERENCE FRAME
- RETRIEVE RAW SEGMENT DATA, NEARLY REGISTERED
- RESAMPLE AND ESTIMATE RESIDUAL PARAMETER DEVIATION
- RECONSTRUCT FINAL IMAGE

C-2

POTENTIAL EFFECT OF SCENE-TO-SCENE
VERSUS SCENE-TO-GROUND REGISTRATION



HOW TO DESIGN A PILOT TEST

- CONCEPTUALIZE DESIGN OF AN INVENTORY SYSTEM
- CONSTRUCT COMPONENTS OF THE INVENTORY SYSTEM
- CONSTRUCT AN ERROR MODEL WHICH PREDICTS SYSTEM PERFORMANCE IF THE COMPONENT PERFORMANCE IS KNOWN
  - SAMPLING ASPECTS
  - MEASUREMENT ASPECTS
- DESIGN PILOT TEST TO MEASURE PERFORMANCE OF THE MAJOR COMPONENTS IN SCENARIO OF CONCEPTUALIZED SYSTEM

SUMMARY OF CRITICAL ISSUES

- PERFORMANCE MEASURES AND GOALS
- SAMPLING TECHNIQUES
  - WITH AND WITHOUT PRIOR STRATIFICATION
  - MULTIPLE YEARS
- MEASUREMENT TECHNIQUES
  - BASIC SEPARABILITY
  - SIGNATURES
  - DIRECT PROPORTION ESTIMATION
  - ANALYST ROLES
- ERROR/PERFORMANCE MODEL
- REGISTRATION
- DESIGN OF PILOT TEST

ANALYST LABELING/PROCEDURE M EXPERIMENT

SEPTEMBER 1979

PRESENTED BY:

R. C. CICONE AND W. F. PONT

OUTLINE OF PRESENTATION

- Objectives
- Approach
- Summary of Progress and Results
- Experiment Design
- Analyst Response
- Analyses of Analyst Labeling
- Summary

OBJECTIVES

- GAIN AN UNDERSTANDING OF THE AI LABELING PROCESS IN A FIELD-LABELING ENVIRONMENT

- EVALUATE A SPRING SMALL GRAIN CONFIGURATION OF PROCEDURE M USING ANALYST LABELS.

APPROACH

- UTILIZE PROCEDURE M AS A TEST-BED
- DESIGN LABELING EXPERIMENT
  - UTILIZE NORTHERN GREAT PLAINS BLIND SITE DATA BASE
  - DEVELOP LABELING PROCEDURES FOR FIELD-LIKE TARGETS
  - INCORPORATE MECHANISMS TO ENSURE STATISTICAL STABILITY
- UTILIZE LACIE ANALYSTS FOR LABELING OF TARGETS
- CONDUCT ANALYSIS OF LABELING PERFORMANCE
  - USE OBJECTIVE STATISTICAL TECHNIQUES TO EVALUATE:
    - AI CONSISTENCY
    - AI ACCURACY
    - ERROR SOURCES
  - USE SUBJECTIVE TECHNIQUES TO EVALUATE SAME
- CONDUCT ANALYSES OF SPRING SMALL GRAINS PROCEDURE M CONFIGURATION

PROGRESS TO DATE

- ANALYST LABELING OF 18 NORTHERN GREAT PLAINS SEGMENTS COMPLETE
- DATA BASE CONSTRUCTED (UTILIZING SPSS STRUCTURE)
  - ANALYST LABELS
  - GROUND TRUTH
  - BLOB STATISTICS
  - HAZE AND SUN ANGLE CORRECTED BRIGHTNESS, GREENNESS
  - CROP PROFILE DESCRIPTORS
  - DERIVED DATA
- OBJECTIVE EVALUATION OF ANALYST PERFORMANCE UNDERTAKEN
  - ON 13 N. DAKOTA SEGMENTS
- PROCEDURE M EVALUATION AWAITS DELIVERY OF SPRING WHEAT LABELER

MAJOR FINDINGS

- NON-GRAIN LABELING ACCURACY IS SIGNIFICANTLY GREATER THAN GRAIN LABELING ACCURACY.
- SPRING WHEAT LABELING ACCURACY IS SIGNIFICANTLY GREATER THAN OTHER SPRING SMALL GRAIN LABELING ACCURACY.
- ANALYSTS ARE OFTEN INCONSISTENT WITH ONE ANOTHER IN LABEL ASSIGNMENTS.
- SIGNIFICANT RELATIONSHIPS EXIST BETWEEN LABELING ACCURACY, AND BLOB SIZE AND PURITY FOR ALL CROP CLASSES.
- ANALYSTS CONSISTENTLY MISLABEL ABOUT 20% OF SPRING SMALL GRAIN TARGETS.
  - AS A CLASS, THESE TARGETS DISPLAY SPECTRAL DIFFERENCES FROM CORRECTLY LABELED SPRING SMALL GRAINS.
  - BLOBS WHOSE PROFILE DIAGNOSTICS DEVIATE FROM SEGMENT NORM ARE MORE OFTEN INCORRECTLY LABELED.

EXPERIMENT DESIGNS

- MINIMAL REQUIREMENTS ARE:
  - THE SET OF TREATMENTS IN STUDY
  - THE SET OF EXPERIMENTAL UNITS IN STUDY (SUBJECTS)
  - THE RULES AND PROCEDURES BY WHICH THE TREATMENTS ARE ASSIGNED TO THE EXPERIMENTAL UNITS (OR VICE VERSA)
  - THE MEASUREMENTS THAT ARE MADE ON THE EXPERIMENTAL UNITS AFTER THE TREATMENTS HAVE BEEN APPLIED

- OTHER PROPERTIES THAT EXPERIMENT DESIGNS SHOULD HAVE ARE:
  - HYPOTHESES: HYPOTHETICAL RELATIONSHIPS BETWEEN MEASUREMENTS, TREATMENTS, AND SUBJECT
  - STATISTICAL TEST TO BE USED IN TESTING THE HYPOTHESES

AI LABELING EXPERIMENT DESIGN

- TREATMENTS
  - THREE EXPERIENCED LACIE ANALYSTS
- SUBJECTS
  - ALL BIG BLOBS FOR 18 LACIE TY 1978 BLIND SITES
- PROCEDURE
  - EACH SEGMENT LABELED BY EACH ANALYST INDEPENDENTLY
  - EACH ANALYST LABELED SEGMENT IN A PRE-ARRANGED RANDOM ORDER
  - EACH ANALYST RELABELED THE FIRST THREE SEGMENTS AFTER ALL SEGMENTS HAD BEEN LABELED
- ANALYSTS DEVELOPED LABELING STRATEGY

AI LABELING EXPERIMENT DESIGN (CONT.)

- MEASUREMENTS
  - SEGMENT AND OVERALL COMMENT FORMS FILLED OUT BY ANALYSTS
  - EACH BLOB GIVEN ONE OF EIGHT CODES INDICATING GRAIN/NON-GRAIN, MIXED/PURE, AND CONFIDENT/DOUBTFUL STATUS
  - EACH BLOB HAS GREENNESS AND BRIGHTNESS VALUES FOR EACH ACQUISITION
  - EACH BLOB IS ASSOCIATED WITH--
    - NUMBER OF PIXELS IN BLOB
    - NUMBER OF PIXELS IN THE INTERIOR
    - GROUND TRUTH CROP CODES

AI LABELING EXPERIMENT DESIGN (CONT.)

DESCRIPTIVE STATISTICS USED FOR INVESTIGATION INCLUDED:

- CONTINGENCY TABLES
- FREQUENCY TABLES
- TWO-DIMENSIONAL SCATTERGRAMS
- PLOTS

ALSO, WE ARE USING THE FOLLOWING STATISTICAL PROCEDURES TO ADDRESS THE QUESTIONS

- ANOVA
- REGRESSION
- DISCRIMINANT ANALYSIS

AI LABELING EXPERIMENT DESIGN (CONT.)

- HYPOTHESES: THIS EXPERIMENT IS ENVISIONED AS EXPLORATORY IN NATURE IN ORDER TO DEVELOP HYPOTHESES AND EVALUATE THEM INSOFAR AS THE DATA PERMITS.

ANALYST OBSERVATIONS/COMMENTS

STRONG POINTS

- BLOBS EASIER TO LABEL THAN DOTS
- BLOBS REPRESENT FIELD CENTERS RATHER WELL

PROBLEM AREAS

- DIFFICULT TO LABEL 300 TO 400 BLOBS
- SMALL BLOBS (LT3 PIXELS) DIFFICULT TO LABEL
- BLOB DOES NOT WORK WELL IN SMALL OR STRIPPED FIELDS
- MIXED BLOBS OCCUR
- ACQUISITIONS USED FOR BLOBBING NOT ALWAYS OPTIMUM
- SINGLE BLOBS MAY BE DISJOINT (DIFFICULT TO LABEL)

PRESENTATION OF LABELING ACCURACY ANALYSIS

- GENERAL INFORMATION
  - GROUND TRUTH STATISTICS
  - QUASI-FIELD STATISTICS
- ANALYST PERFORMANCE
  - OVERALL
  - BY CROP TYPE
  - AS A FUNCTION OF--
    - BLOB PURITY
    - BLOB SIZE
  - MIXED AND DOUBTFUL LABELS
- ANALYST CONSISTENCY
  - OVERALL CONSISTENCY
  - CONSISTENCY VS ACCURACY
- ERROR UNDERSTANDING
  - AS A FUNCTION OF--
    - SPECTRAL DIFFERENCES
    - PROFILE DIAGNOSTICS

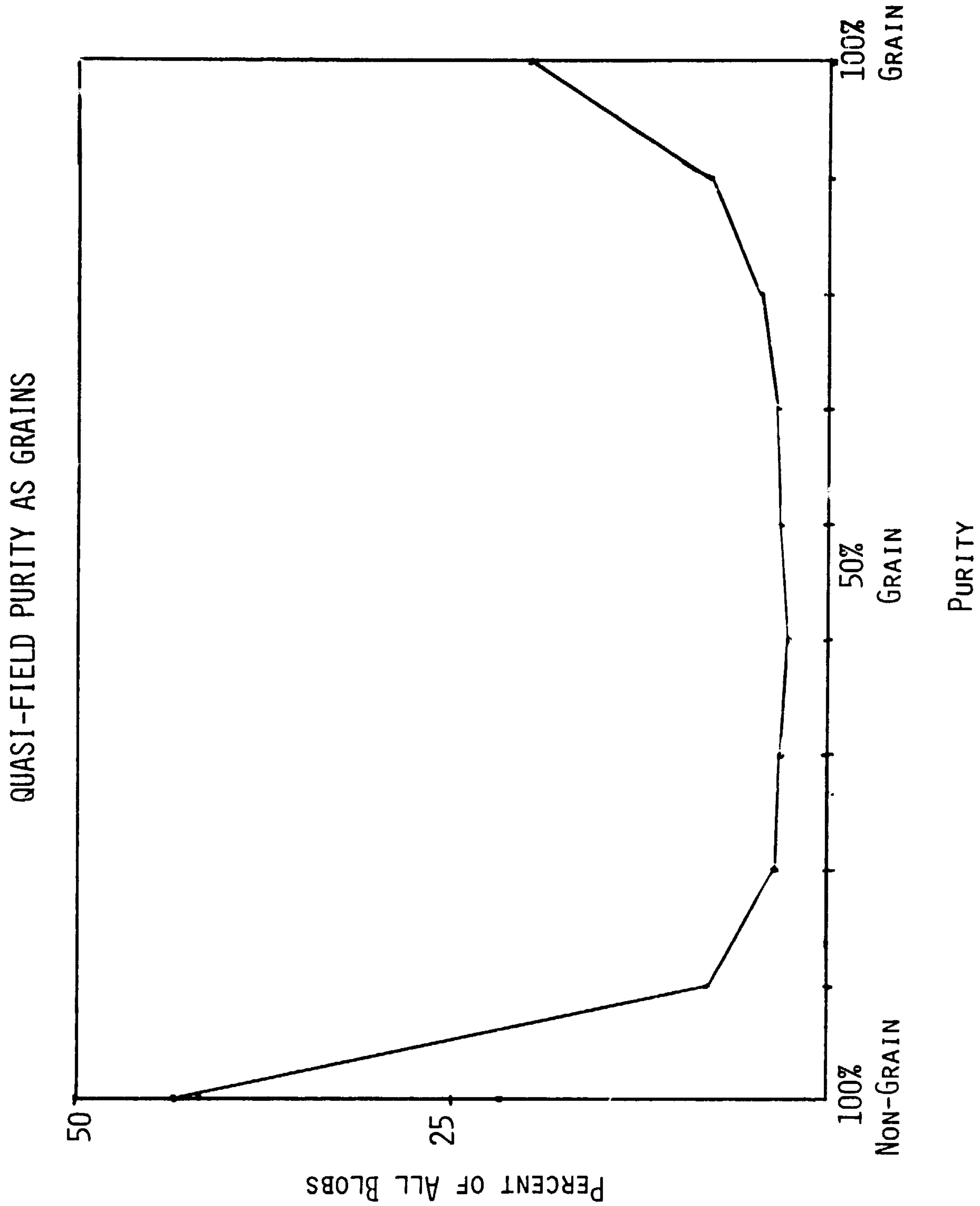
SEGMENT GROUND TRUTH STATISTICS

(GRAIN PROPORTIONS)

SEGMENT	% GRAIN	% WHEAT	% BARLEY	% OATS	% RYE	% UNKNOWN
1392	33.0	26.4	5.4	1.1	0.0	1.5
1457	50.5	37.0	1.2	12.3	0.0	1.0
1461	40.2	31.0	4.6	3.4	1.3	6.0
1467	57.1	35.8	10.7	10.6	0.0	3.0
1473	49.7	31.8	17.0	0.6	0.3	5.3
1602	30.4	26.6	1.1	1.9	0.9	0.6
1612	26.6	11.1	0.3	15.0	0.2	0.5
1619	47.7	35.8	11.5	0.4	0.0	1.3
1636	42.5	35.7	2.1	3.7	0.9	5.8
1650	29.5	23.3	1.3	4.6	0.2	5.7
1653	19.0	14.8	0.4	3.7	0.1	3.3
1656	15.8	2.7	0.4	12.7	0.1	0.9
1920	29.8	14.9	0.5	14.3	0.1	0.4
AVE.	36.3	25.1	4.3	6.5	0.3	

SEGMENT QUASI-FIELD STATISTICS

Segment	# Blobs	# Big Blobs	% of Segment Covered	Blob Purity	Blob RV	Blob ITF
1392	688	380	87.6	92.5	.20	.76
1457	900	401	84.1	95.0	.15	.81
1461	1509	465	71.2	96.9	.08	.92
1467	554	400	91.4	89.2	.32	.67
1473	1353	387	72.6	97.6	.06	.95
1602	1298	399	70.5	97.0	.09	.90
1612	577	329	90.8	94.0	.22	.78
1619	916	379	79.5	96.6	.09	.89
1636	1060	427	80.1	93.1	.20	.75
1650	862	397	81.3	85.7	.44	.58
1653	613	339	89.0	96.6	.19	.85
1656	631	322	87.5	95.6	.19	.83
1920	436	299	95.2	93.8	.20	.80
		Total - 4924	Ave. - 83.1	Ave. - 94.1		
		Ave. - 379				



QUASI-FIELD PURITY AS GRAINS
50
25
PERCENT OF ALL BLOBS
100% NON-GRAIN
50% GRAIN
100% GRAIN
PURITY

OVERALL ANALYST LABELING ACCURACY

- OATS, BARLEY AND RYE ACCURACIES ARE SIGNIFICANTLY LOWER THAN SPRING WHEAT ACCURACIES (ESPECIALLY OATS).
- SUMMER CROPS (EXCEPT FLAX) AND GRASSES WERE NOT A PROBLEM WITH RESPECT TO ERRORS OF COMMISSION.
- BETWEEN-SEGMENT VARIATIONS IN THE LABELING OF SPRING WHEAT ARE SUBSTANTIAL.
- THE PROBABILITY OF A GIVEN LABEL APPEARS FUNCTIONALLY RELATED TO THE BLOB PURITY.
- ANALYST ACCURACY IMPROVES AS BLOB SIZE INCREASES.
- BLOBS LABELED DOUBTFUL ARE ASSIGNED TO A CLASS WITH LITTLE CORRELATION TO ITS ACTUAL COMPOSITION.
- BLOBS LABELED MIXED CORRESPOND TO ACTUAL BLOB PURITY, BUT NUMBER FAR FEWER THAN THOSE ACTUALLY PRESENT.

OVERALL ANALYST LABELING ACCURACY[1,2]

(NORTH DAKOTA SEGMENTS)

SEGMENT	VOTE		GREEN		RED		BLUE	
	NG	G	NG	G	NG	G	NG	G
ALL	95.4	65.4	94.7	67.0	90.0	70.1	95.5	50.6
1392	90.6	84.5	88.1	87.6	76.6	93.0	96.1	43.3
1457	97.3	63.8	94.5	68.2	96.7	65.6	97.3	45.0
1461	95.4	78.5	91.9	79.3	88.6	86.6	98.3	58.5
1469	82.5	55.3	79.2	68.1	76.6	58.7	90.8	25.8
1473	98.1	88.5	93.6	87.0	98.7	96.8	97.4	70.3
1602	96.1	78.2	97.7	76.6	94.9	82.9	94.5	74.2
1612	95.7	50.0	97.0	46.5	93.0	53.5	93.1	38.4
1619	98.2	67.2	97.6	71.7	94.5	70.2	97.6	56.1
1636	95.9	57.9	94.1	61.5	91.3	58.7	96.8	57.0
1650	95.8	52.1	96.7	43.2	90.6	61.5	71.5	59.4
1653	96.4	63.1	98.8	35.3	91.2	80.6	93.1	59.7
1656	97.9	9.2	99.2	15.4	94.6	3.1	95.9	16.9
1920	98.9	43.3	98.4	39.6	97.8	47.4	97.2	32.3

1. QUASI-FIELDS WERE AT LEAST 50% PURE.
2. PERCENT OF BLOBS CORRECTLY LABELED.

ANALYST LEARNING TRENDS

(REWORKED NORTH DAKOTA SEGMENTS)

ANALYST/NO. SEG.	INITIAL ACCURACY		REWORK ACCURACY		TOTAL CHANGES	
	G	NG	G	NG	TOTAL	CORRECT
GREEN (2)	54.7	98.9	50.0	98.7	42	16
RED (2)	68.4	94.6	87.1	93.3	151	104
BLUE (3)	59.5	92.8	64.0	92.3	158	87

PERCENTAGE OF MAJOR CROP QUASI-FIELDS LABELED AS GRAIN[1]

(NORTH DAKOTA SEGMENTS)

	Analysts							
	Vote	Green	Red	Blue	% Purity	% of Pixels Considered	% of All Pixels	# Segments
Spring Crops	71.3	73.8	74.5	57.4	93.3	39.6	25.1	13
Summer Crops	2.5	2.7	12.6	1.0	94.6	9.1	5.8	12
Pasture & Grass	0.8	0.2	3.2	1.5	94.4	32.7	20.8	11
Fallow	2.3	2.8	8.0	1.8	91.7	13.2	8.4	13
Miscellaneous	1.3	3.7	1.1	2.4	96.1	3.4	2.2	11
Unknown & Strip	36.3	32.2	48.1	42.3	91.2	2.0	1.3	9

1. Quasi-fields are at least 80% pure within the assigned class.

PERCENTAGE OF GRAIN CROP QUASI-FIELDS LABELED AS GRAIN[1]

(NORTH DAKOTA SEGMENTS)

	Analysts					#	#
	Vote	Green	Red	Blue	% Purity	Quasi-Fields Labeled	Segments
Spring Wheat	83.8	86.3	86.1	73.5	91.2	663	13
Barley	67.0	72.3	76.9	39.4	92.9	122	9
Oats	26.7	28.7	28.6	19.2	96.9	222	13
Rye	17.5	22.2	21.0	5.7	93.2	13	5

1. QUASI-FIELDS ARE AT LEAST 80% PURE WITHIN THE ASSIGNED CLASS.

AI LABELING ACCURACY OF MAJOR GRAINS BY VOTE[1,2]

EACH NORTH DAKOTA SEGMENT

SEGMENT	GRAIN	WHEAT	WHEAT (HARVESTED)	OATS	BARLEY
1392	90.5	90.7	92.1	-	-
1457	64.9	81.8	80.0	31.7	-
1461	81.9	86.2	81.0	-	-
1467	55.3	50.0	-	30.8	91.7
1473	89.9	97.7	97.4	-	78.0
1602	88.3	91.8	91.8	-	-
1612	47.4	84.6	85.7	16.1	-
1619	71.2	92.6	-	-	18.5
1636	59.4	61.4	-	-	-
1650	76.9	66.7	68.4	-	-
1653	71.1	68.0	66.7	-	-
1656	9.8	-	-	8.3	-
1920	36.7	71.4	71.4	20.0	-

1. QUASI-FIELDS AT LEAST 80% PURE.
2. AT LEAST 10 QUASI-FIELDS REQUIRED.

PERCENTAGE OF NON-GRAIN QUASI-FIELDS LABELED AS GRAIN[1]

(NORTH DAKOTA SEGMENTS)

	VOTE	GREEN	RED	BLUE	% PURITY	# QUASI-FIELDS LABELED	# SEGMENTS
ALFALFA	0.0	0.0	3.5	3.8	89.7	20	7
CORN	1.0	0.0	1.0	1.0	91.8	15	5
SAFFLOWER	0.0	0.0	25.6	0.0	94.2	6	2
SUNFLOWER	1.6	2.0	1.3	0.0	94.4	162	8
SOYBEANS	0.0	0.0	0.0	0.0	94.1	30	1
SUGAR BEETS	0.0	0.0	0.0	0.0	94.8	9	2
FLAX	23.1	23.1	46.0	0.0	91.7	24	6
POTATOES	0.0	0.0	9.0	0.0	93.9	21	1
PASTURE	0.6	0.0	0.9	0.6	93.9	379	10

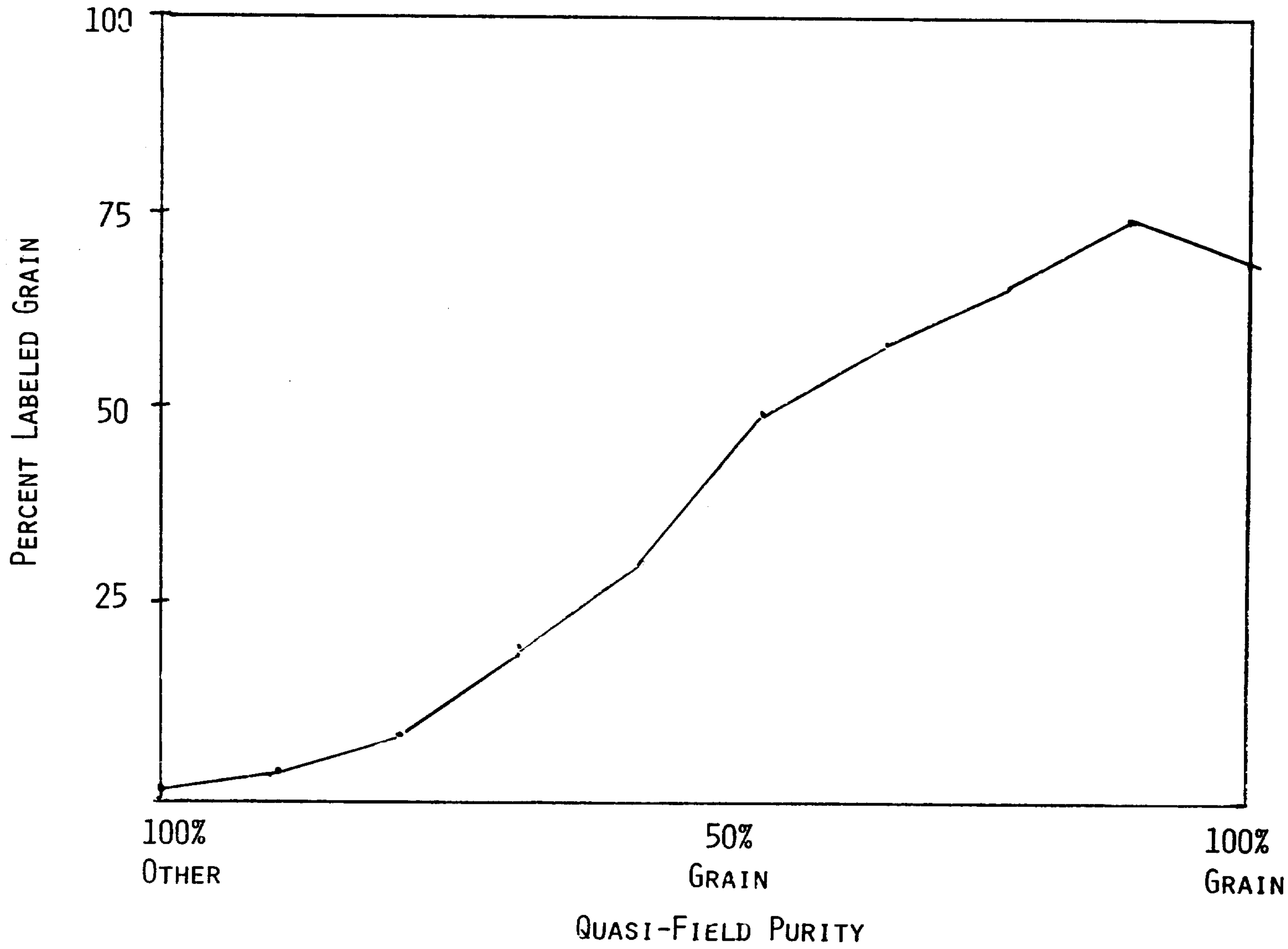
1. QUASI-FIELDS ARE AT LEAST 80% PURE WITHIN THE ASSIGNED CLASS.

ANALYST LABELING PERFORMANCE AS A FUNCTION OF QUASI-FIELD PURITY

(NORTH DAKOTA SEGMENTS)

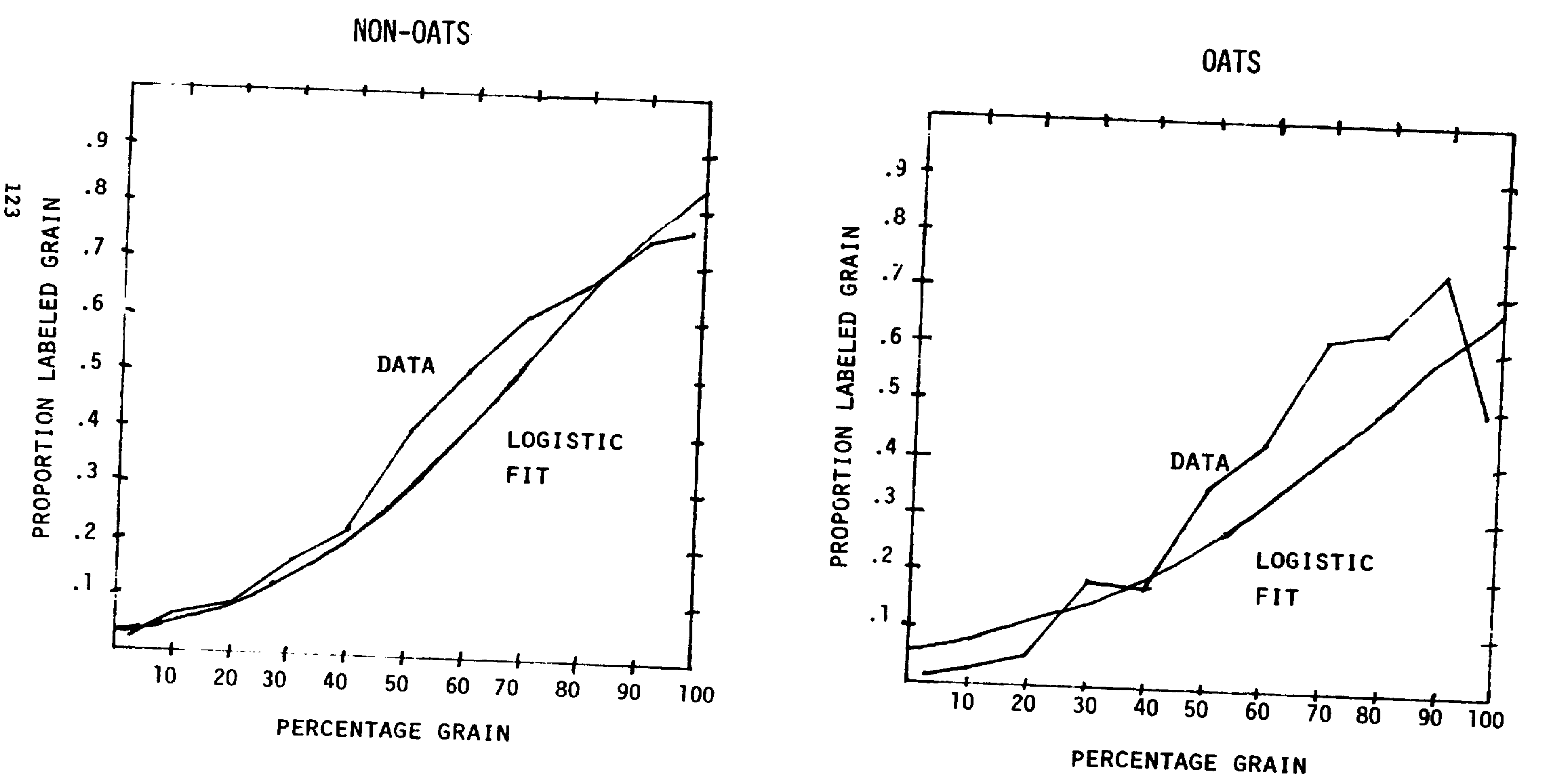
	PERCENT GRAIN IN QUASI-FIELD									
	0-9	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-99
PERCENT LABELED GRAIN	1.5	3.4	8.3	19.9	30.3	49.5	58.5	66.0	74.6	68.5
SIZE OF STRATA (# OF QUASI-FIELD)	1894	398	210	174	143	176	175	253	383	942
SIZE OF STRATA (% OF TOTAL PIXELS IN BIG BLOBS)	43.5	7.8	3.5	3.2	2.7	3.2	3.4	4.7	8.1	19.9

ANALYST LABELING PERFORMANCE AS A FUNCTION OF QUASI-FIELD PURITY



LABELING CHARACTERISTICS AS A FUNCTION

OF GRAIN PURITY FOR NON-OATS AND OATS



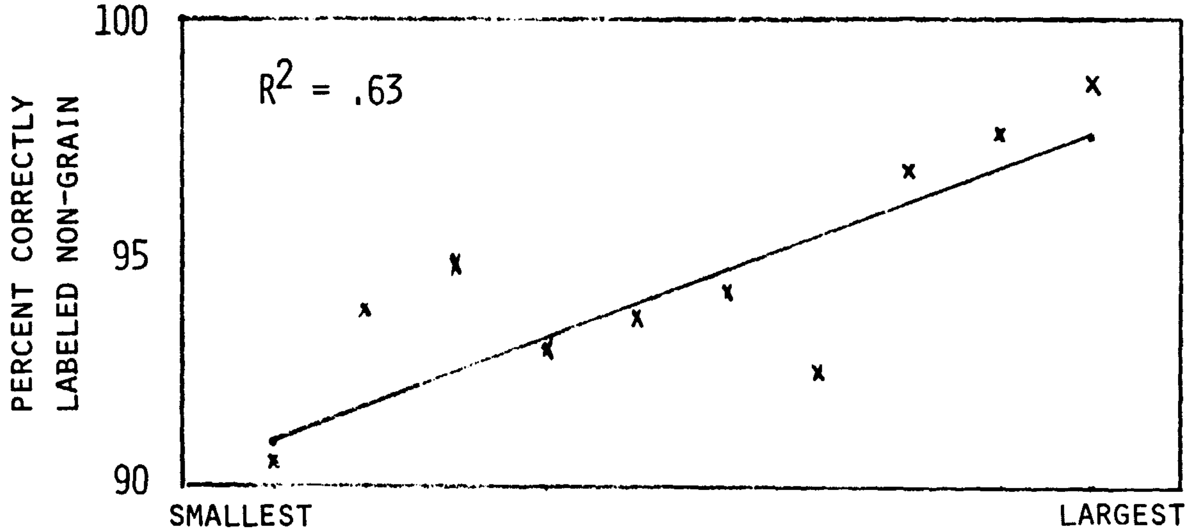
ANALYST LABELING ACCURACY AS A FUNCTION OF QUASI-FIELD SIZE

(NORTH DAKOTA SEGMENTS)

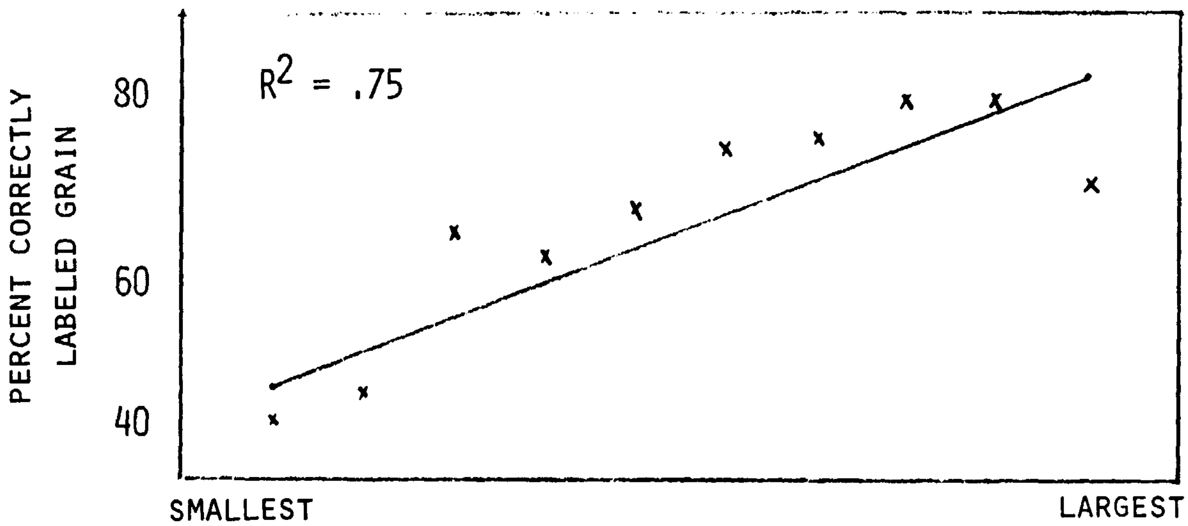
SIZE* STRATA (# INTERIOR PIXELS	VOTE		GREEN		RED		BLUE	
	NG	G	NG	G	NG	G	NG	G
1	90.6	42.9	88.1	44.3	85.3	53.4	91.6	32.3
2	93.9	44.7	89.9	46.4	89.6	53.6	91.8	40.8
3	94.8	62.3	92.4	63.9	88.9	67.2	91.8	42.6
4-6	93.0	58.4	93.3	60.2	86.0	64.3	93.6	44.4
7-9	93.8	64.0	92.0	66.5	87.2	69.5	97.1	47.0
10-14	94.1	70.2	93.1	70.4	86.5	71.8	94.8	50.2
15-19	92.4	71.5	94.8	71.0	87.1	75.8	92.9	57.8
20-28	96.9	75.2	97.7	70.9	91.4	78.2	96.9	61.4
29-46	97.6	75.2	97.9	75.2	93.4	77.2	96.9	60.6
47-120	98.7	67.6	98.7	76.3	95.8	69.8	98.7	55.5

*EACH STRATA CONTAINS APPROXIMATELY 10% OF ALL QUASI-FIELDS.

ANALYST LABELING ACCURACY AND FIELD SIZE



BLOB SIZE



ANALYST DOUBTFUL LABEL PERFORMANCE

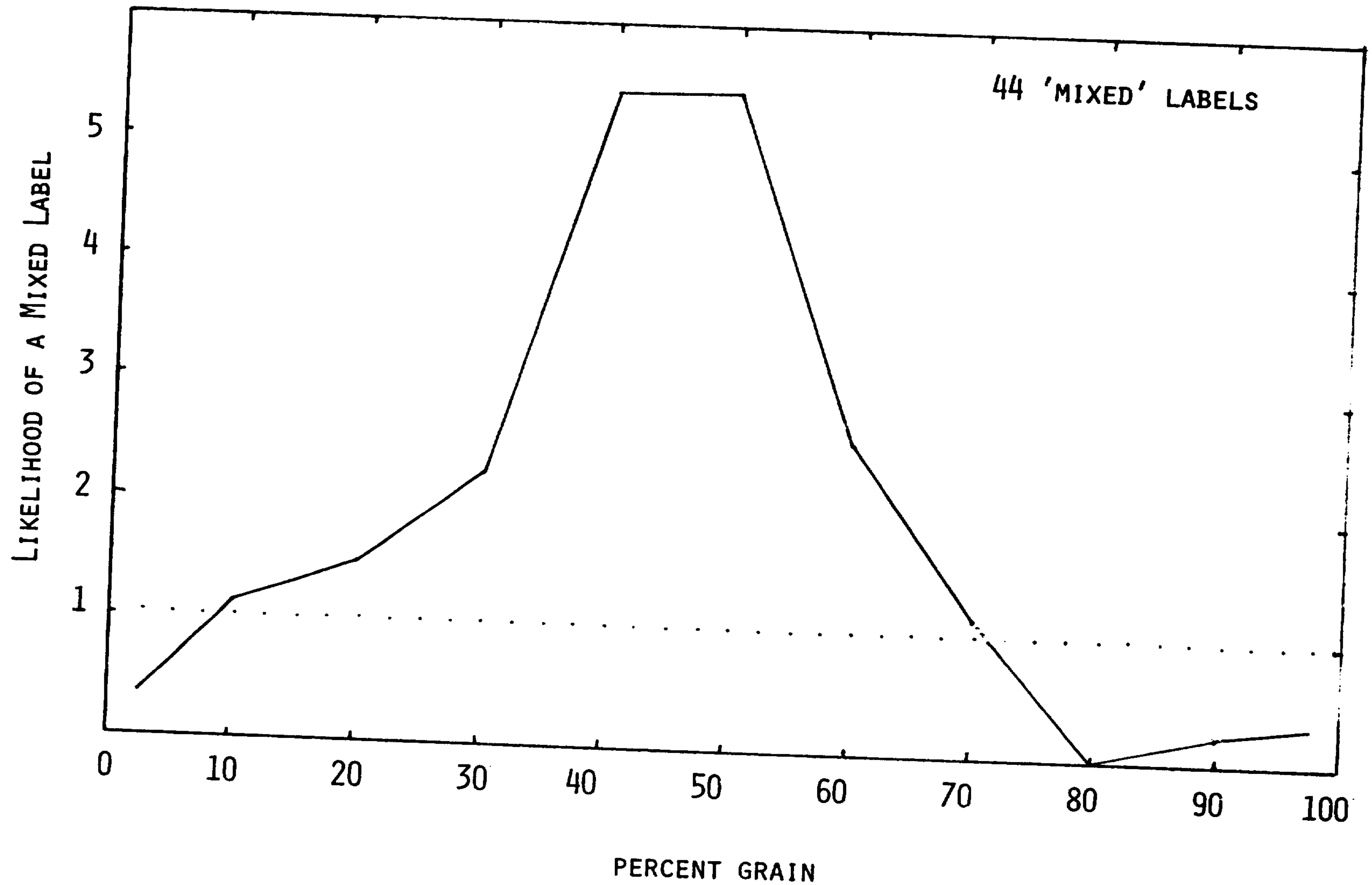
Purity As A Grain	Analyst Decisions				Fraction Labeled Grain		
	Doubtful		Not Doubtful		Doubtful	Not Doubtful	Ratio
	G	NG	G	NG			
0-20%	22	25	351	6694	.47	.05	9.4
21-40%	8	7	229	948	.53	.19	5.3
41-60%	23	11	384	544	.68	.41	1.7
61-80%	31	17	691	540	.65	.56	1.2
81-100%	121	62	2293	1207	.66	.66	1.0

NORMALIZED NUMBER OF MIXED LABELS

VS

PERCENT GRAIN

(FOR AI GREEN)

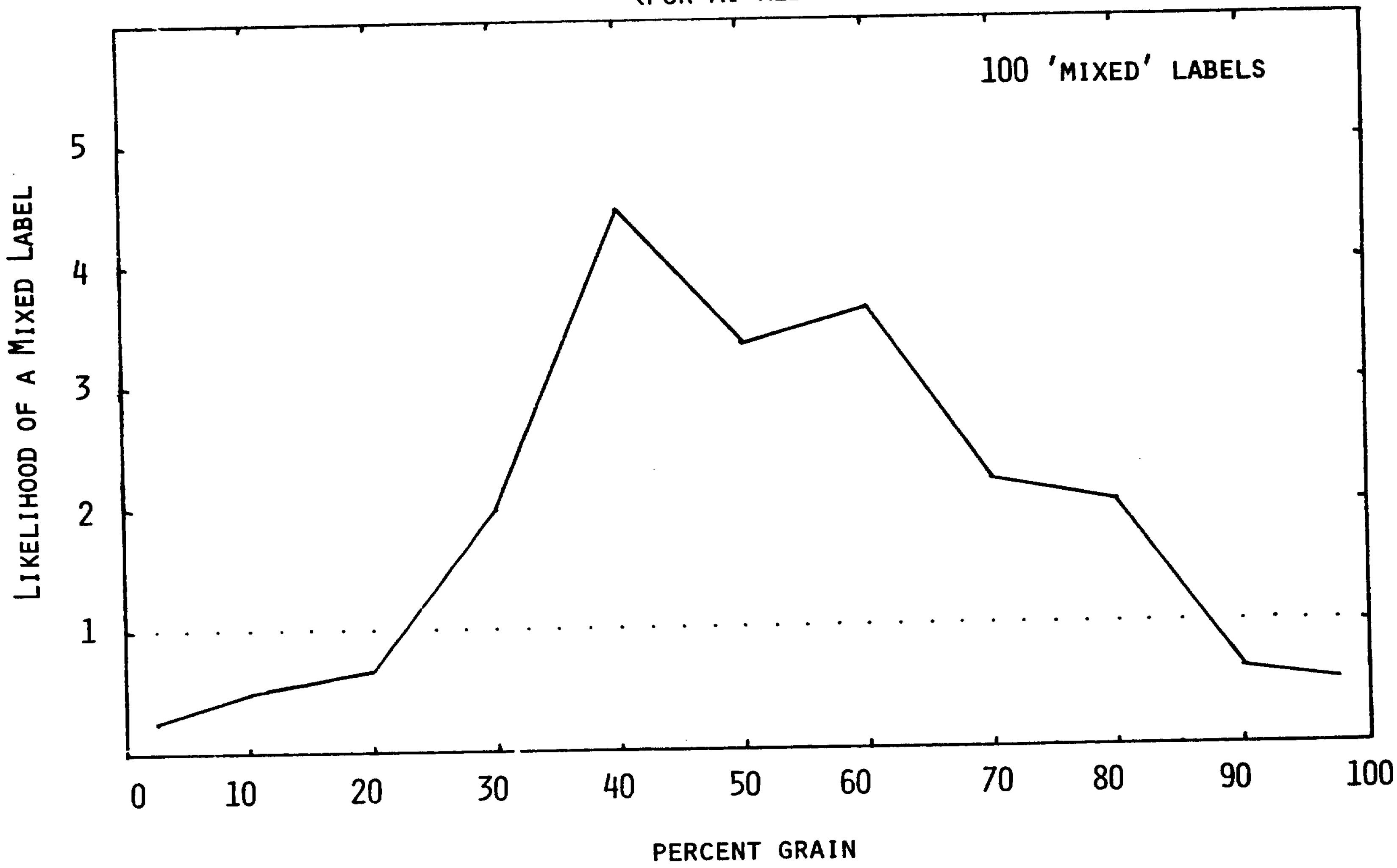


NORMALIZED NUMBER OF MIXED LABELS

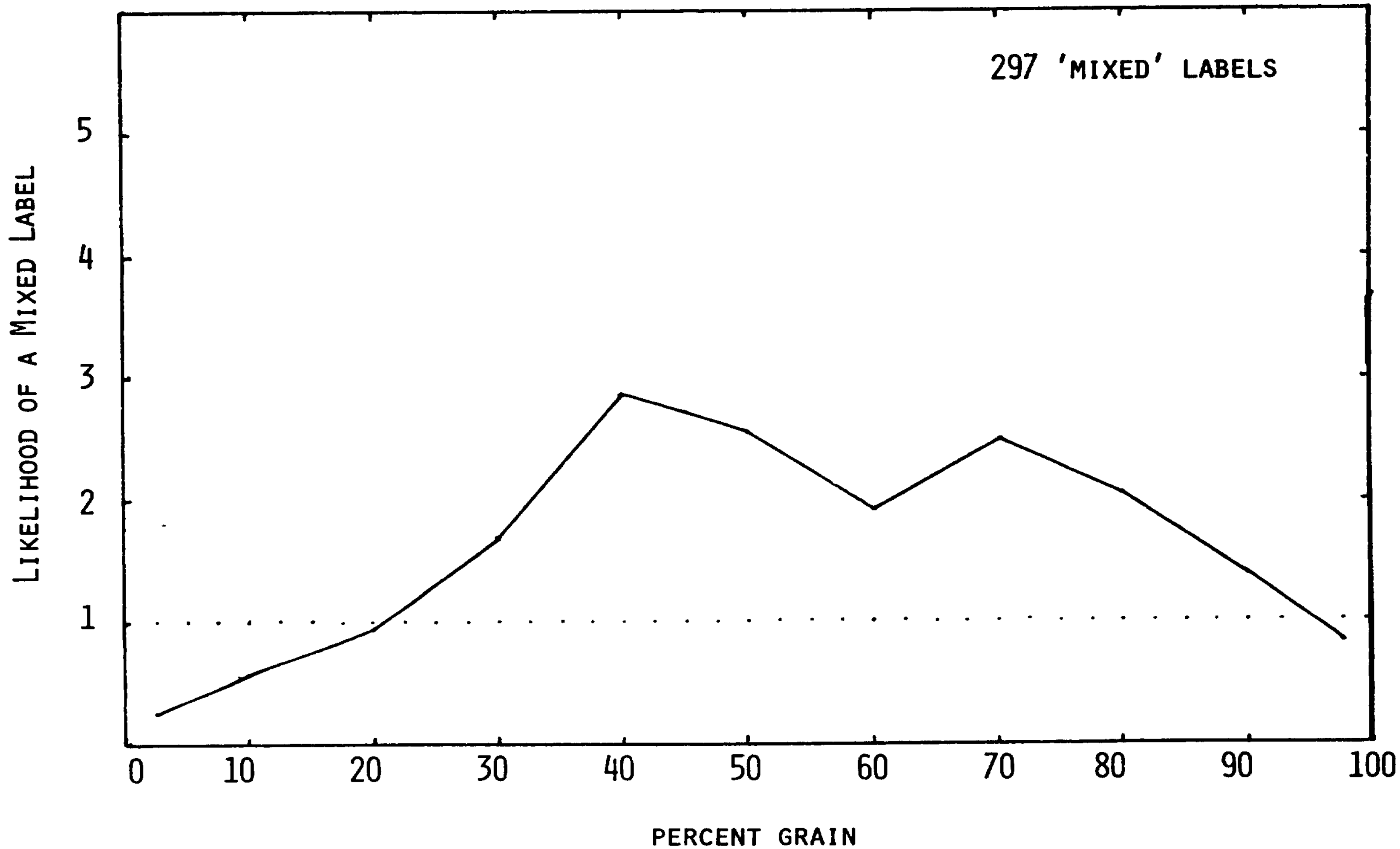
VS

PERCENT GRAIN

(FOR AI RED)



NORMALIZED NUMBER OF MIXED LABELS
VS
GRAIN PERCENT
(FOR AI BLUE)



ANALYST CONSISTENCY

- THE PERCENT OF ANALYST LABELS IN AGREEMENT RANGES FROM 55.7 TO 92.7% ACROSS SEGMENTS, SUGGESTING A VARYING PERCEPTION OF A GRAIN SIGNATURE BETWEEN ANALYSTS.
- A SUBSTANTIAL PERCENTAGE OF GRAIN BLOBS WERE MISLABELED BY ALL THREE ANALYSTS, SUGGESTING AN UPPER BOUND TO CONSENSUS LABELING ACCURACY.
- CONSENSUS BREEDS ACCURACY IN LABELING NON-GRAINS AND SPRING WHEAT, INACCURACY IN LABELING OATS.

ANALYST CONSISTENCY

PERCENT OF DECISIONS IN AGREEMENT

SEGMENT	GREEN RED	GREEN BLUE	RED BLUE	RED GREEN BLUE
1380	94.9	96.4	94.2	$\boxed{92.7}$
1392	82.6	73.9	66.7	61.6
1457	90.6	83.4	83.5	79.1
1461	88.0	83.6	80.6	76.3
1467	79.4	60.5	71.5	$\boxed{55.7}$
1473	91.2	84.3	83.3	79.5
1518	91.7	82.2	80.5	77.0
1566	91.4	84.8	86.2	81.0
1602	93.0	91.8	91.1	88.0
1612	92.0	90.2	90.5	86.4
1619	88.5	85.9	87.6	80.8
1636	86.7	85.8	84.4	73.5
1650	80.8	79.9	81.3	71.2
1653	73.9	85.2	76.5	68.0
1656	91.0	92.8	91.9	87.9
1825	90.3	89.0	84.4	81.9
1835	92.2	92.9	92.0	88.8
1920	91.9	89.0	89.8	85.2

ANALYST CONSISTENCY

PERCENT OF DECISIONS IN CORRECT AGREEMENT

Analyst Pair	Non-Grain	>50% Grain	>80% Grain	Wheat	Oats	Barley	Summer Crop	Pasture & Grass
Green Red	85.3	59.5	64.5	79.2	15.9	57.6	85.1	96.4
Green Blue	89.3	43.8	49.5	67.2	15.0	28.8	95.0	98.0
Red Blue	85.4	46.2	51.7	68.5	16.8	34.7	84.4	96.2
Vote	93.8	64.7	68.9	82.7	20.4	63.5	96.3	99.4

ANALYST CONSISTENCY

PERCENT OF DECISIONS IN CORRECT AGREEMENT

No. Analysts Correct	Non-Grain	> 50% Grain	>80% Grain	Wheat	Oats	Barley	Summer Crop	Pasture & Grass
0 of 3	1.7	21.5	19.9	7.8	61.4	15.3	0.3	0.0
1 of 3	4.6	13.9	11.2	9.6	10.0	21.2	3.3	0.6
2 of 3	10.7	22.3	20.5	16.6	6.9	34.7	12.2	3.8
3 of 3	83.1	42.4	48.4	66.1	13.6	28.8	84.1	95.6

ANALYST CONSISTENCY

PERCENT OF DECISIONS IN CORRECT AGREEMENT AS A RANDOM EVENT

(ANALYST ACCURACIES AS PRIOR PROBABILITIES)

NO. CORRECT	NON-GRAIN	>50% GRAIN	>80% GRAIN	WHEAT	OATS	BARLEY	SUMMER CROP	PASTURE & GRASS
0 OF 3	0.2	4.9	2.8	0.5	41.1	3.9	.003	.001
1 OF 3	1.1	26.3	20.2	7.9	42.8	25.6	15.3	.05
2 OF 3	17.4	45.0	45.4	37.4	24.5	48.6	48.3	4.8
3 OF 3	81.4	23.8	31.5	54.2	4.1	21.9	84.2	95.2

PROBABILITY OF CORRECT LABELING AS A FUNCTION OF AGREEMENT

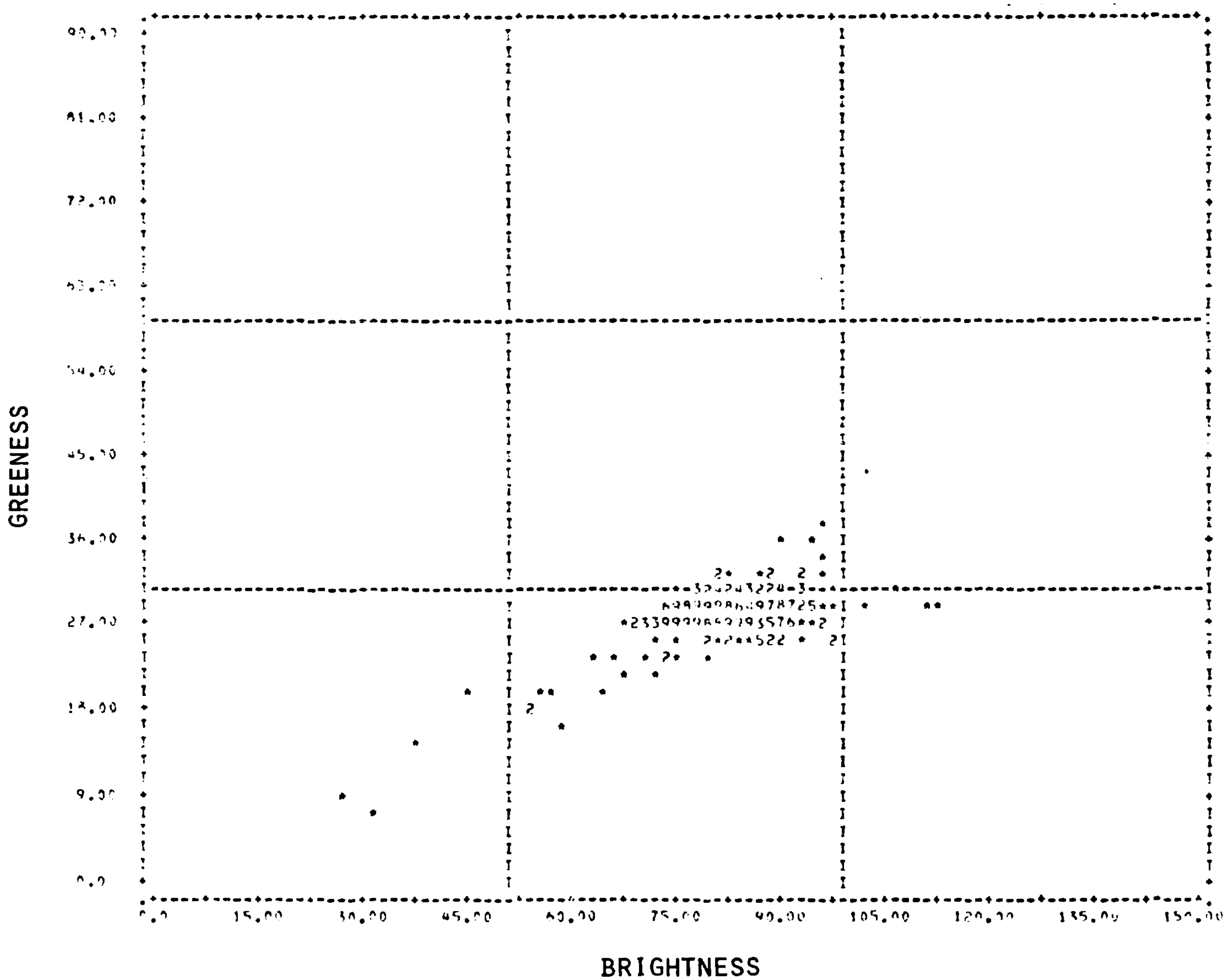
No. Analysts In Agreement	Non-Grain	> 50% Grain	> 80% Grain	Wheat	Oats	Barley	Summer Crop	Pasture & Grass
2	69.9	61.6	64.7	63.4	40.8	62.1	78.7	86.4
3	98.0	66.4	70.9	89.4	18.1	65.3	99.6	100.0

ERROR UNDERSTANDING

- GRAINS ARE MISLABLED AS THEY DO NOT CONFORM TO A 'STANDARD' SPECTRAL PROFILE.
  - CORRECTLY LABELED GRAINS EXHIBIT SIMILAR SPECTRAL PROFILES ACROSS ALL SEGMENTS.
  - INCORRECTLY LABELED GRAIN TRAJECTORIES DIFFER DISTINCTLY.
  - LINEAR DISCRIMINANT ANALYSIS OF CROPS AT A SEGMENT LEVEL REVEALED ACCURACY PATTERNS SIMILAR TO ANALYSTS.
  - A STANDARD WHEAT SIGNATURE CONCEPT MAY BE KEY TO ANALYST LABELING BEHAVIOR.
- DISTINCTIVE RELATIONSHIPS WERE OBSERVED BETWEEN LABELING ACCURACY OF GRAINS AND PROFILE DERIVATES, SHIFT AND PEAK GREEN.
  - ERROR INCREASES AS SHIFT DEVIATES EARLY OR LATE FROM THE SEGMENT NORM.
  - ERROR INCREASES WHEN PEAK GREEN IS LOW.
  - ERRORS ARISING FROM LATE SHIFT ARE NOT AS PROMINANT IN THE PRESENCE OF HIGH PEAK GREEN VALUES.

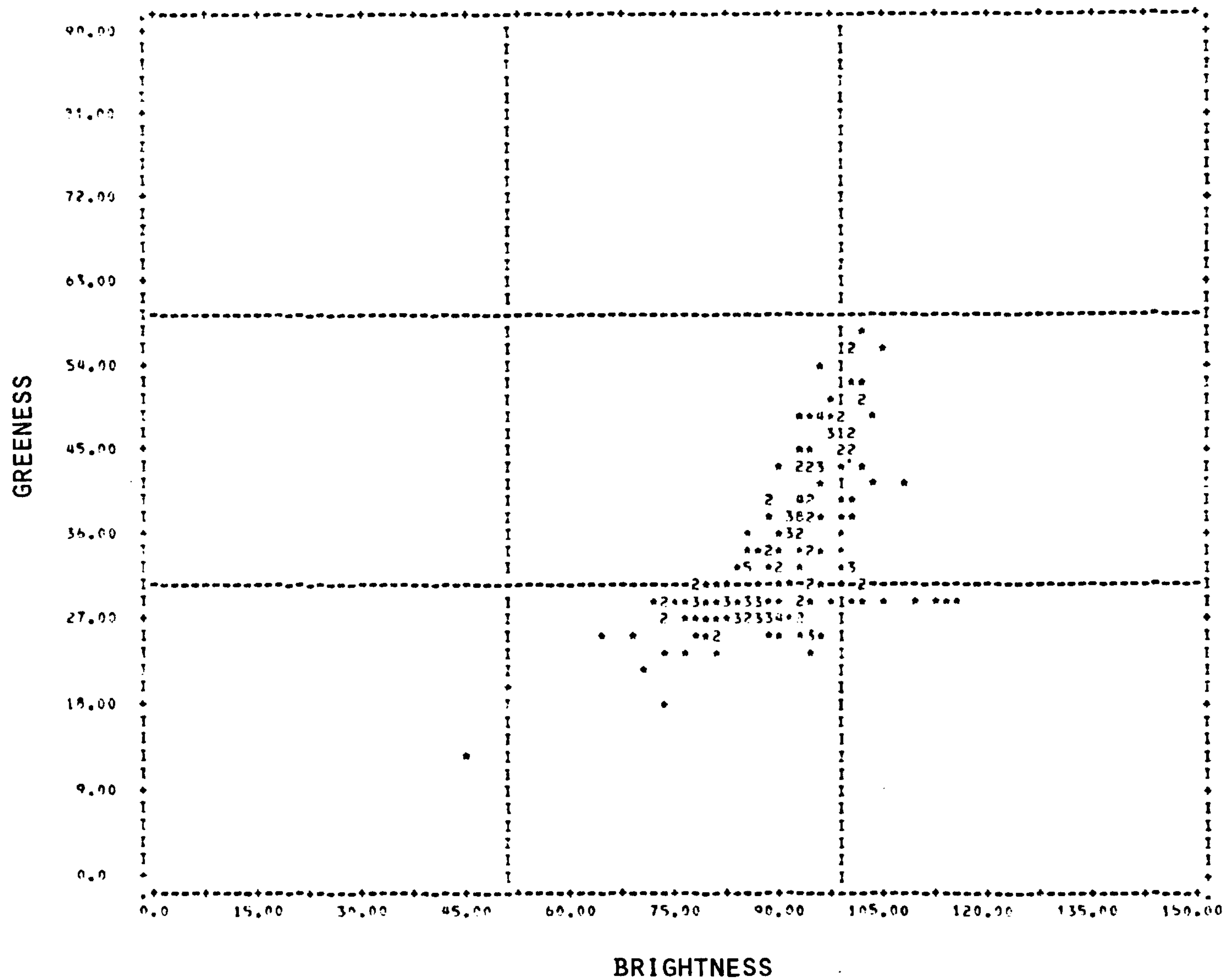
GRAINS LABELED CORRECTLY BY ALL ANALYSTS

LANDSAT II CYCLE 2



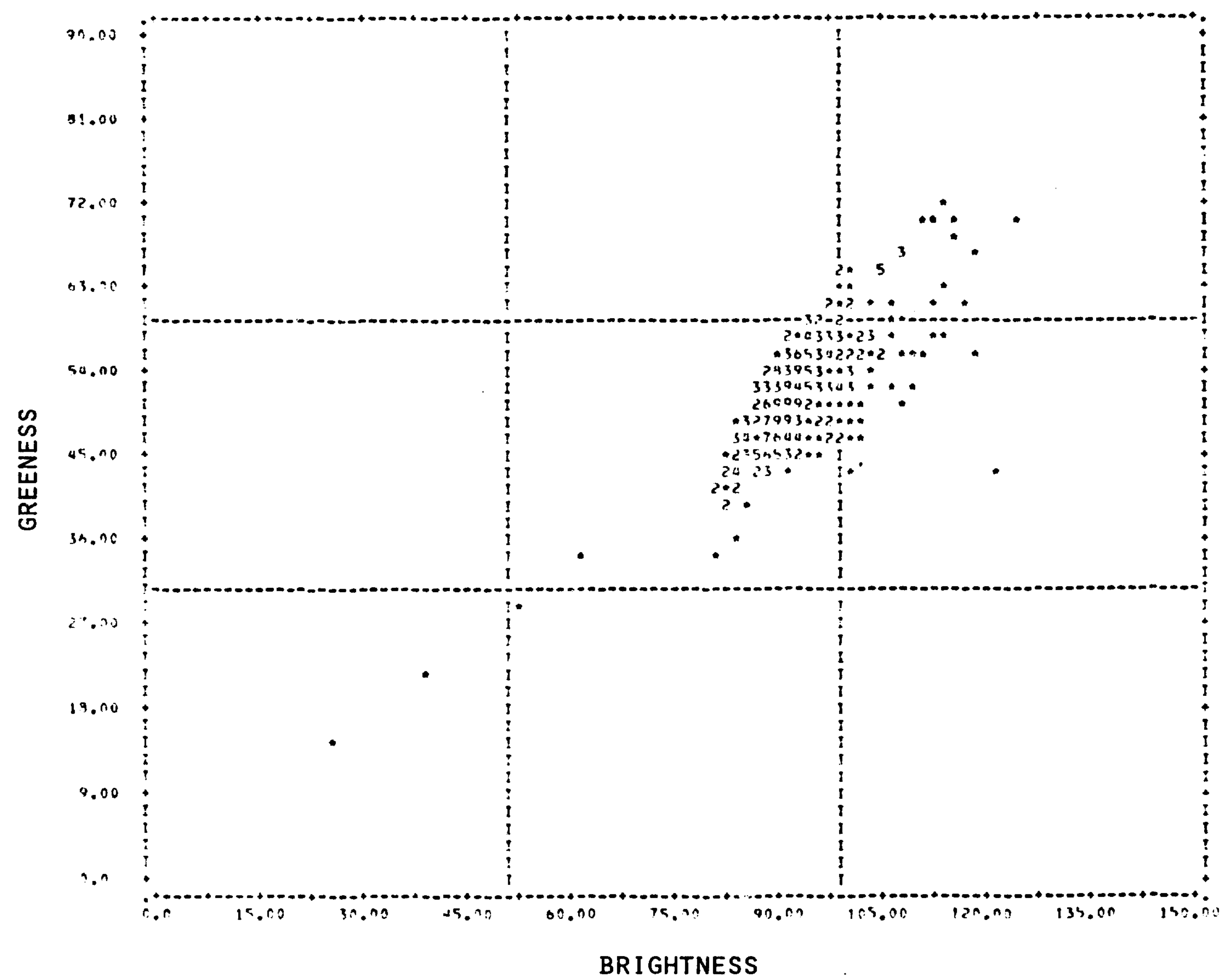
GRAINS LABELED INCORRECTLY BY ALL ANALYSTS

LANDSAT II CYCLE 2



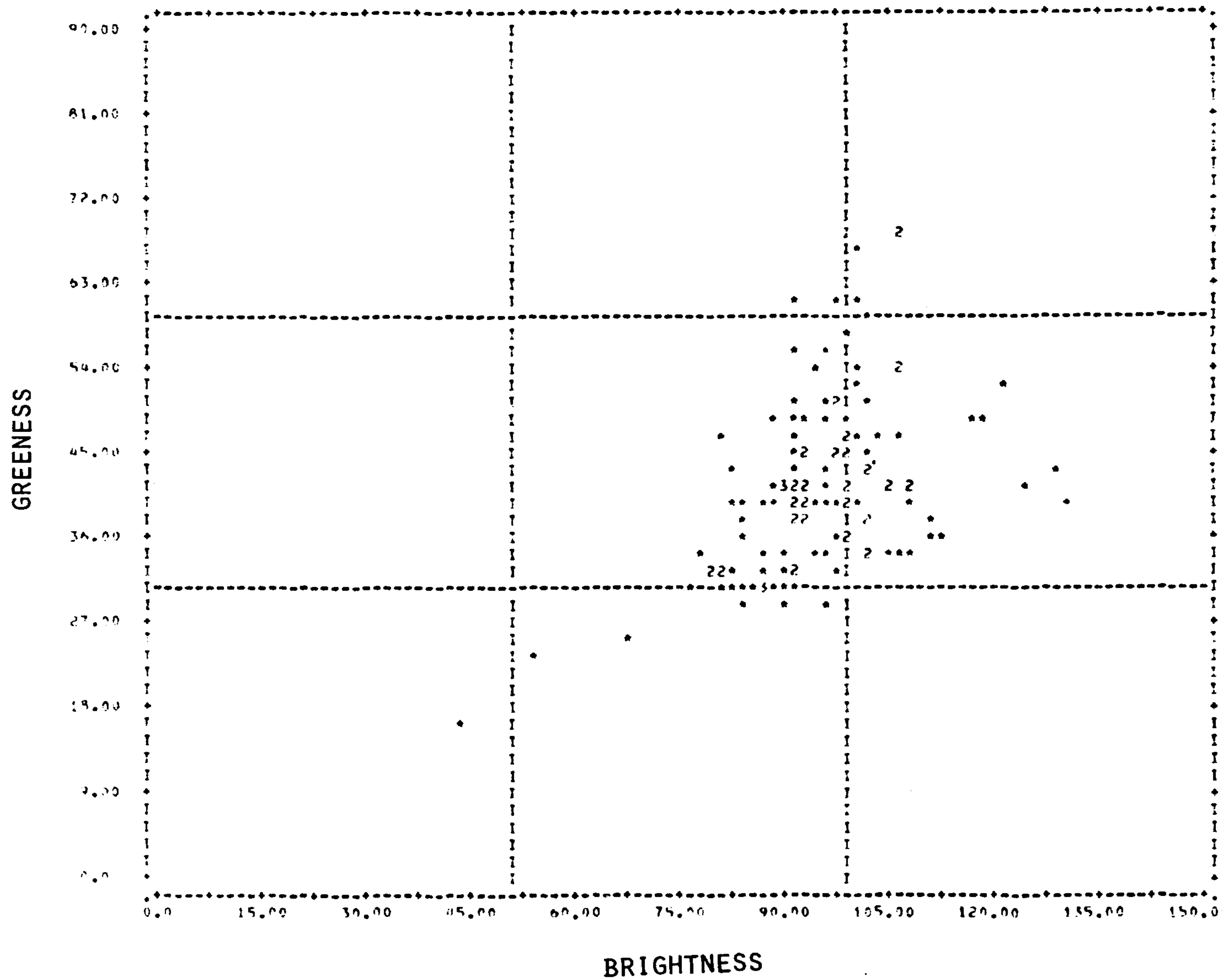
GRAINS LABELED CORRECTLY BY ALL ANALYSTS

LANDSAT III CYCLE 6



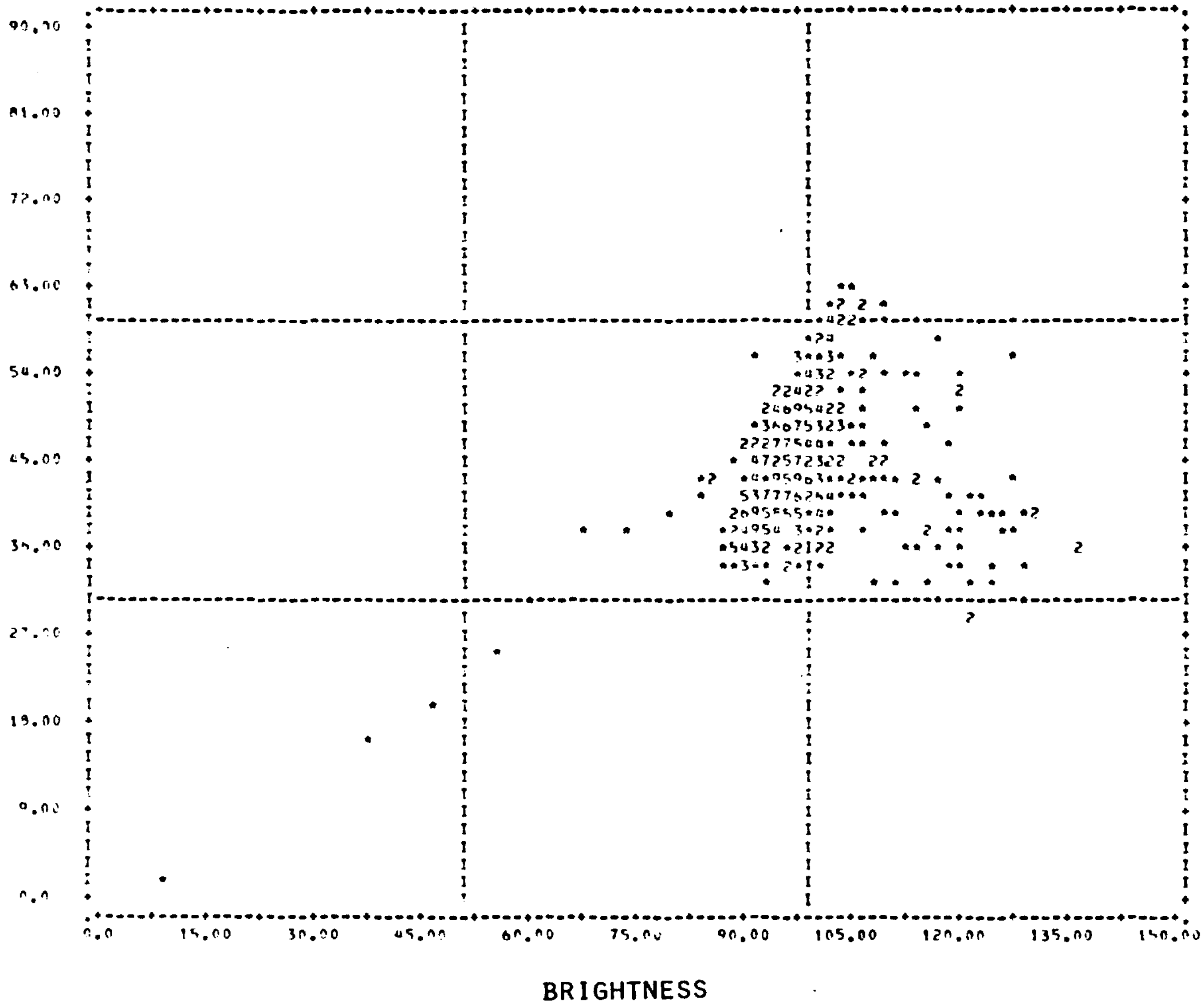
GRAINS LABELED INCORRECTLY BY ALL ANALYSTS

LANDSAT III CYCLE 6



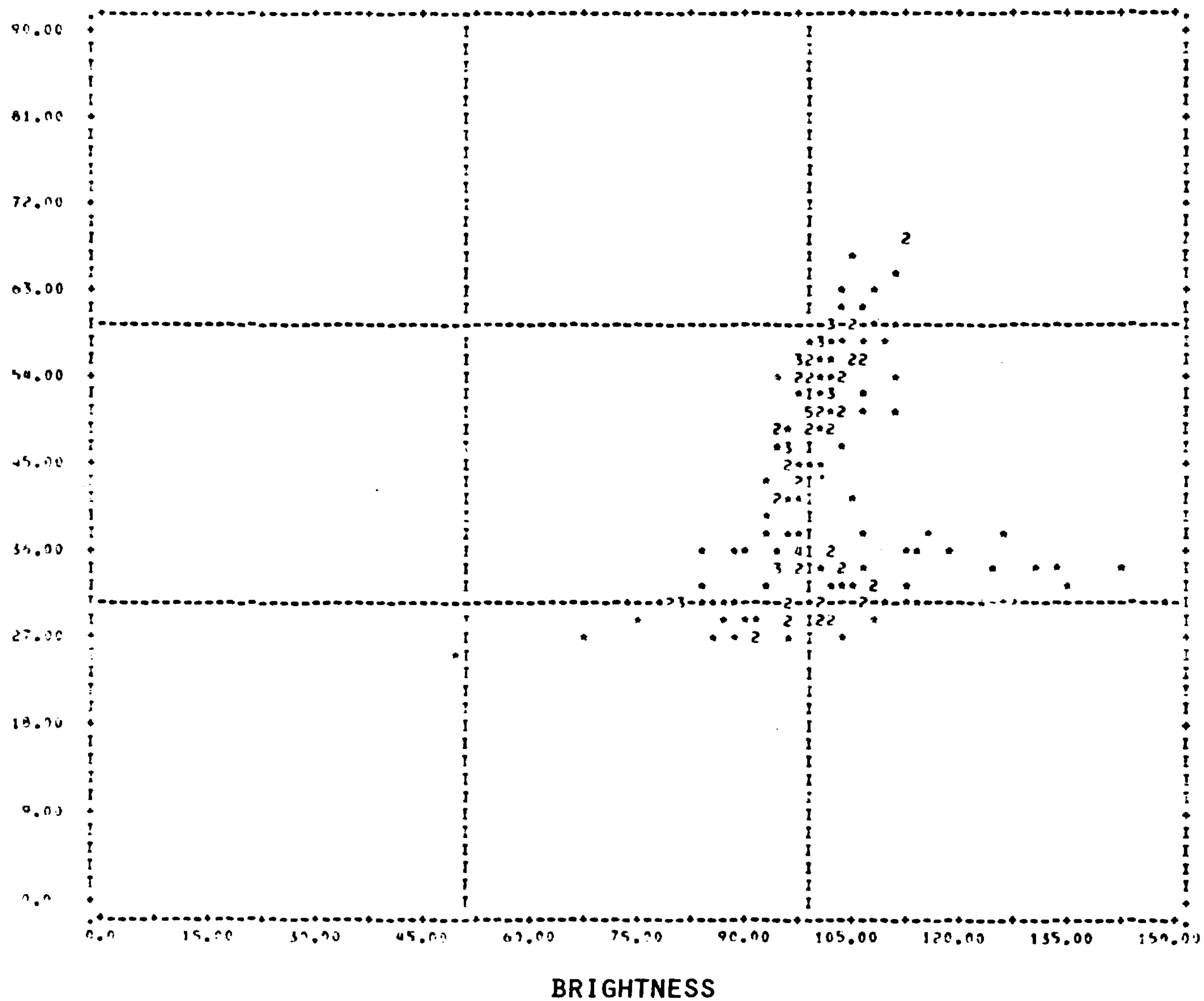
GRAINS LABELED CORRECTLY BY ALL ANALYSTS

LANDSAT II CYCLE 7



GRAINS LABELED INCORRECTLY BY ALL ANALYSTS

LANDSAT II CYCLE 7



PERFORMANCE OF A LINEAR DISCRIMINANT

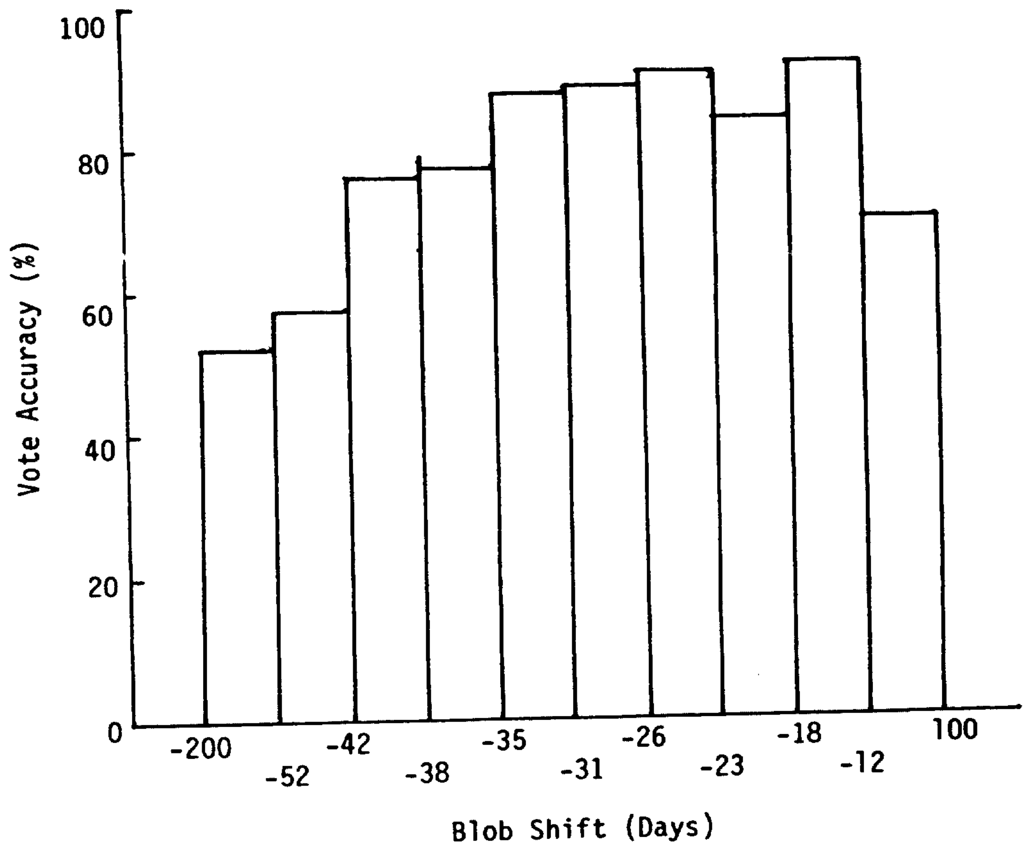
Segment 1467				
	W	B	O	NG
W	71.1	2.9	11.4	8.6
B	7.7	92.3	0.0	0.0
O	15.4	5.1	62.5	17.9
NG	12.3	0.0	11.3	76.4

Segment 1612			
	W	O	NG
W	87.5	6.3	6.3
O	11.5	50.0	38.5
NG	1.9	37.7	60.4

Segment 1619			
	W	B	NG
W	97.6	1.2	1.2
B	18.5	81.5	0.0
NG	1.4	3.5	95.1

SPRING SMALL GRAINS LABELING ACCURACY VS SHIFT

BLOB PURITY ⩾ 80%
OATS EXCLUDED
SEGMENT 1619 EXCLUDED



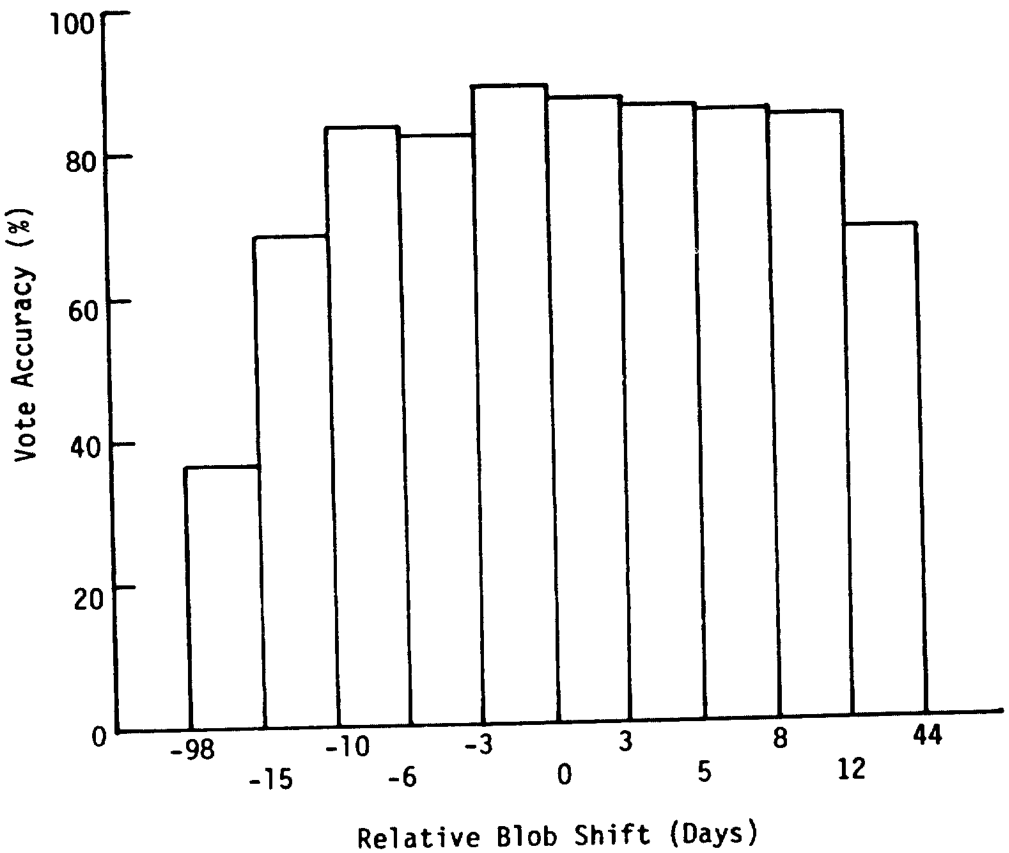
SPRING SMALL GRAINS LABELING ACCURACY VS RELATIVE SHIFT

RELATIVE BLOB SHIFT = BLOB SHIFT - AVERAGE SHIFT IN EACH SEGMENT

BLOB PURITY ≥ 80%

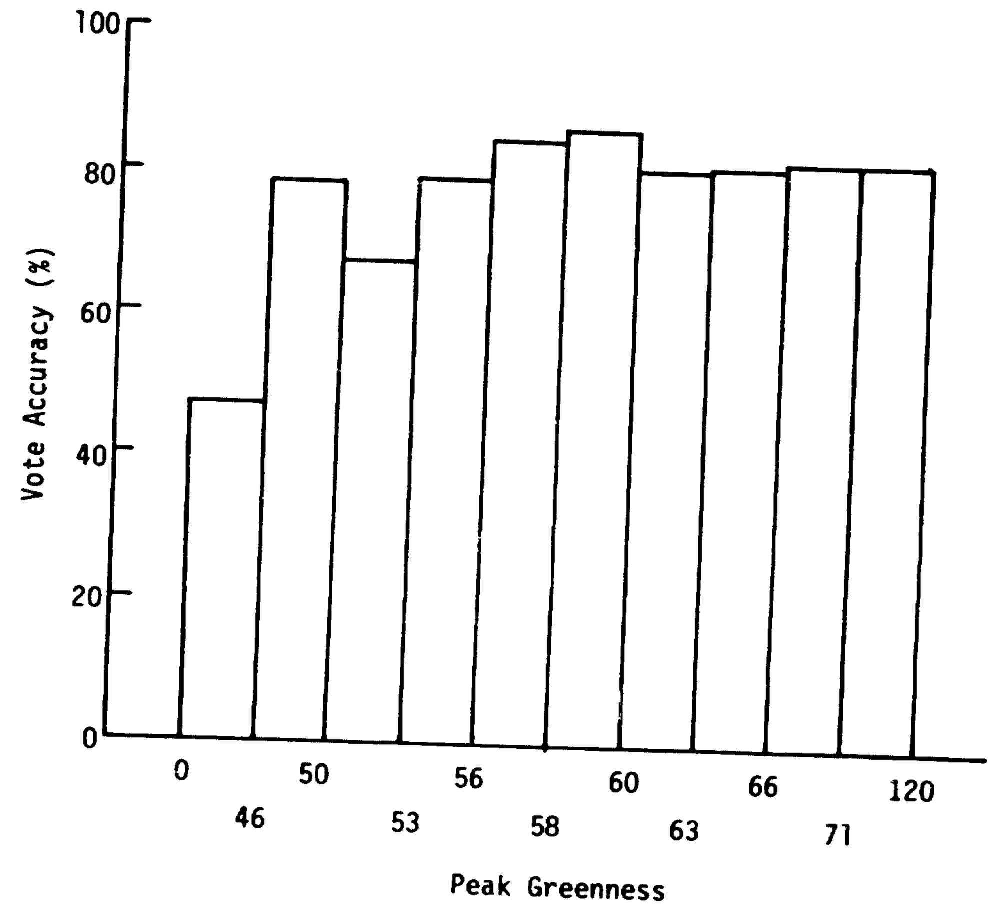
OATS EXCLUDED

SEGMENT 1619 EXCLUDED



SPRING SMALL GRAINS LABELING ACCURACY VS PEAK GREENNESS

BLOB PURITY ≥ 80%
OATS EXCLUDED
SEGMENT 1619 EXCLUDED



RECOMMENDATIONS

- CONDUCT A LARGE SCALE, COMPREHENSIVE EXPERIMENT TO PURSUE MORE DEFINITELY UNDERLYING PATTERNS IN ANALYST LABELING BEHAVIOR
  - DESIGN-DRIVEN DATA BASE
  - WELL-DEFINED LABELING TARGETS
  - MULTI-ANALYST
  - MULTICROP
  - CONFIDENCE LABELING
  - INDEPENDENT AND INTERACTIVE LABELING
  - PERFORMANCE VS ACQUISITION IN HISTORY (AND TIME OF YEAR)
- EXPLORE ABSOLUTE CROP SEPARABILITY IN LANDSAT DATA
- PURSUE AN ANALYST LABELING MODEL, NOT TO ACHIEVE ONE (FOR YOU WILL BE FRUSTRATED BY ITS ILLUSIVENESS AS THE ANALYST IS ETERNALLY ADAPTABLE) BUT TO GAIN UNDERSTANDING AND ESTABLISH BASIC PATTERNS IN LABELING BEHAVIOR IN ORDER TO ADAPT OVERALL SYSTEM STRUCTURE TO THOSE PATTERNS

PLANS

- INCORPORATE MINNESOTA SEGMENTS INTO DATA BASE AND COMPLETE ANALYSIS
  - EXAMINE THE RELATIONSHIPS BETWEEN ANALYST LABELING AND EFFECTIVE ACQUISITION HISTORY OF THE TARGET
  - FURTHER EXPLORE THE HYPOTHESIS THAT GRAIN LABELING IS DRIVEN BY A STANDARD SIGNATURE CONCEPT BOTH IN TERMS OF EXPECTED SPECTRAL BEHAVIOR AND EXPECTED CROP CALENDAR
- EVALUATE PROCEDURE M SYSTEM AND COMPONENTS IN LIGHT OF ANALYST LABELS
- CONSIDER STRUCTURE OF COMPREHENSIVE EXPERIMENT AND CONTINUE TO PROMOTE THE NOTION!

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